BMJ Open

Exposure to heavy physical work from early to later adulthood and primary health care visits due to musculoskeletal diseases in midlife: a register linked study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-031564
Article Type:	Research
Date Submitted by the Author:	10-May-2019
Complete List of Authors:	Halonen, Jaana; Finnish Institute of Occupational Health Shiri, Rahman; Finnish Institute of Occupational Health, Centre of Expertise for Health and Work Abili Mänty, Minna; University of Helsinki, Department of Public Health Sumanen, Hilla; South-Eastern Finland University of Applied Sciences, Health care and emergency care; University of Helsinki, Public Health Solovieva, Svetlana; Finnish Institute of Occupational Health, Center of Expertice for Health and workability Viikari-Juntura, Eira; Finnish Institute of Occupational Health, Kahonen, Mika; University of Tampere , Department of Clinical Physiology; Tampere University Hospital Lehtimaki, Terho Raitakari, Olli; University of Turku, Research Centre of Applied and Preventive Cardiovascular Medicine; Turku University Hospital, Department of Clinical Physiology and Nuclear Medicine Lallukka, Tea; Tyoterveyslaitos, ; Helsingin Yliopisto Laaketieteellinen tiedekunta, Department of Public Health
Keywords:	Musculoskeletal disorders < ORTHOPAEDIC & TRAUMA SURGERY, Physical work, Spine < ORTHOPAEDIC & TRAUMA SURGERY, Upper extremity, OCCUPATIONAL & INDUSTRIAL MEDICINE

Research article: BMJ Open

Exposure to heavy physical work from early to later adulthood and primary health care visits due to musculoskeletal diseases in midlife: a register linked study

Jaana I. Halonen,[1] Rahman Shiri,[1] Minna Mänty,[2,3] Hilla Sumanen,[3,4] Svetlana Solovieva,[1] Eira Viikari-Juntura,[1] Mika Kähönen,[5] Terho Lehtimäki,[6] Olli T. Raitakari,[7,8,9] Tea Lallukka[1,3]

1 Finnish Institute of Occupational Health, Helsinki, Finland
2 City of Vantaa, Finland
3 Department of Public Health, University of Helsinki, Helsinki, Finland
4 South-Eastern Finland University of Applied Sciences, Kotka, Finland
5 Department of Clinical Physiology, Tampere University Hospital, and Finnish Cardiovascular Research Center - Tampere, Faculty of Medicine and Health Technology, Tampere University, Tampere 33521, Finland
6 Department of Clinical Chemistry, Fimlab Laboratories, and Finnish Cardiovascular Research Center - Tampere, Faculty of Medicine and Health Technology, Tampere University, Tampere 33520, Finland
7 Centre for Population Health Research, University of Turku and Turku University Hospital, Turku, Finland.
8 Research Centre of Applied and Preventive Cardiovascular Medicine, University of Turku, Turku, Finland.
9 Department of Clinical Physiology and Nuclear Medicine, Turku University Hospital, Turku, Finland.

Corresponding author: Jaana I. Halonen, address: Finnish Institute of Occupational Health, 70032 TYÖTERVEYSLAITOS, Finland

E-mail: jaana.halonen@ttl.fi Telephone: +358 43 82 44 264

Running title Physical work from early to later adulthood and musculoskeletal visits

Word count 2437

Abstract (258/300)

Objectives: To examine whether exposure to heavy physical work from early to later adulthood is associated with primary health care visits due to cause-specific musculoskeletal diseases in midlife.

Design: Prospective cohort study

Setting: Nationally representative Young Finns Study cohort, Finland.

Participants: 1061 participants of the Young Finns Study cohort.

Exposure measure: Physical work exposure was surveyed in early (18–24 years old, 1986 or 1989) and later adulthood (2007 and 2011), and it was categorized as: "no exposure", "early exposure only", "later exposure only", and "early and later exposure".

Primary and secondary outcome measures: Visits due to any musculoskeletal disease and separately due to spine disorders, and upper extremity disorders were followed-up from national primary health care register from the date of the third survey in 2011 until 2014.

Results: Those with physically heavy work in early adulthood only had an increased risk of any musculoskeletal disease (risk ratio (RR) 1.55, 95% confidence interval (CI) 1.05−2.28) after adjustment for age, sex, smoking, body mass index, physical activity, and parental occupational class. Later exposure only was associated with visits due to any musculoskeletal disease (RR 1.46, 95% CI 1.01−2.12) and spine disorders (RR 2.40, 95% CI 1.41−4.06). Early and later exposure was associated with all three outcomes: RRs 1.99 (95% CI 1.44−2.77) for any musculoskeletal disease, 2.43 (95% CI 1.42−4.14) for spine disorders, and 3.97 (95% CI 1.86−8.46) for upper extremity disorders.

Conclusions: To reduce burden of musculoskeletal diseases, preventive actions to reduce exposure to or mitigate the consequences of physically heavy work throughout the work career are needed.

Key words: musculoskeletal; physical work; spine disorder; upper extremity

Strengths and limitations of this study

- We used self-reported assessment of physical heaviness of work that was based on a single question, which is why the specificity of the exposure, e.g. regarding exposure of different parts of the body, is low.
- We cannot rule out the possibility of changes in the exposure or outcomes between the survey waves.
- The setting enabled us to prospectively examine the long-term consequences of exposure to early and later physical work and midlife musculoskeletal health problems that were objectively measured.
- The used cohort data were representative of the general population with relatively little loss to follow-up.

Introduction

Musculoskeletal diseases (MSD) are the leading cause of work disability[1] measured as sickness absence[2] and disability retirements.[3] In the European Union, the estimated total cost of lost productivity attributable to MSD among working-aged people can be up to 2% of gross domestic product (GDP).[4] Contextual factors, particularly those related to workplace, have been identified as risk factors for sickness absence and disability retirement due to musculoskeletal problems[5 6] as well as for musculoskeletal pain.[7] We have reported findings where early and cumulative exposure to physical work were associated with low back pain at midlife.[8] However, pain as an outcome is always self-reported, as well as a common condition. Thus, objective outcome measures are needed to confirm whether the effects of early and cumulative physical work are similar for more severe and objectively assessed MSD outcomes.

Only few studies to date have been able to assess the associations between cumulative exposure to physical work and MSD. A recent study used a job exposure matrix to assess exposure at the level of occupational title and disability retirement due to MSD,[6] but even the first exposure measurements were mainly from midlife. In another study, two individual-level measurements were used to examine the associations between long-term exposure to high physical workload in midlife and risk of disability retirement due to MSD after age of 61,[9] while younger employees were not included. Yet another study used individual-level physical work exposure data that were retrospectively assessed, and observed that cumulative exposure may increase the risk of sickness absence and disability retirement, but results for cause-specific outcomes were not reported.[10] In addition to the lack of cumulative exposure data, prior studies have rarely accounted for family background although parental socioeconomic position has been linked, for example, to later musculoskeletal problems[11] and widespread pain.[12]

To fill these gaps in evidence, we examined whether physical heaviness of work from early adulthood to later adulthood is associated with primary health care visits due to MSD in midlife. Any MSD was examined as one outcome group, but we also included two cause-specific groups: disorders of the spine and upper extremities. The contribution of behavioural factors and parental socioeconomic position in these associations were considered.

Methods

Participants

Data for this study are derived from the Young Finns Study.[13] Cohort baseline data were collected in 1980 in six age strata: 3, 6, 9, 12, 15, and 18 years resulting in 3596 participants (response rate 83%). For this study, we included all those who were 18, 21 or 24 years when responding to the survey in 1986 (wave 1). The wave 1 data were completed by including also those who turned 18 years and responded to the survey in 1989 (**Figure 1**.). The age-based selection criterion was applied as the focus of this study was on early work-related exposures. Further inclusion criterion required that the participants responded to the question on physical heaviness of work in 1986 or 1989 (wave 1, early adulthood exposure), and in 2007 (wave 2, later adulthood exposure) and/or in 2011 (wave 3, later adulthood exposure), which resulted in a total of 1170 participants. After excluding those with no follow-up or with missing data on any covariate, the final study sample was 1170 cohort participants who all had work exposure measurement from wave 1. Of these participants, 1023 had work exposure data also from 2007, and 978 had work exposure data also from 2011. The study has been ethically approved by the Ethics Committee of the Hospital District of Southwest Finland.

Patient and Public Involvement statement

Patients or the public were not involved in the development of the research question or the design of this study nor in the conduct of the study.

Exposure

Physical heaviness of work was enquired at waves 1 to 3 with a single question: “How heavy is your work physically?”. There were six response alternatives: 1) light sedentary work, 2) other sedentary work, 3) physically light work, involving standing and moving, 4) medium heavy work involving moving, 5) physically heavy work, and 6) physically very heavy work. The responses were categorized as: sedentary/physically light work, and medium to heavy physical work. We used responses from all three waves to form a five-class exposure variable categorized as: “no exposure”, when reporting sedentary/physically light work in all three waves, “early exposure only”, when reporting medium to heavy physical work only in wave 1, “later exposure only”, when reporting medium to heavy physical work in waves 2 or 3 (89% responded to both waves 2 and 3), and “early and later exposure” when reporting medium to heavy physical work in wave 1 and in later adulthood in wave 2 and/or 3. All other possible response combinations formed a group “inconsistent exposure”.

Outcomes

We examined primary health care visits due to a musculoskeletal diagnosis. The follow-up started from the day after returning wave 3 survey in 2011, and continued until the first primary health care visit, death (from Statistics Finland) or end of the follow-up (end of 2014), whichever occurred first. Data were obtained from the register of primary health care visits (Avohilmo) maintained by National Institute for Health and Welfare.[14] Diagnosis-specific data have been collected and were available from 2011 onwards. Visits due to *any* *musculoskeletal diagnosis* by International Classification of Diseases (ICD) version 10 codes M00-M99 were examined over the follow-up period. Additionally, two cause-specific outcome groups with the largest numbers of events were: 1) disorders of the spine and 2) upper extremity disorders. *Disorders of the spine* included any of the following diseases, surgeries or treatments (ICD-10 code): cervical disc disorders (M50), lumbar and other intervertebral disc disorders with radiculopathy (M51.1), other specified intervertebral disc displacement (M51.2), disc degeneration (M51.3), disc disorders (M51.8), intervertebral disc disorder, unspecified (M51.9), disc disorder/ disc disease (back disorders with radiation: M50, M51), other dorsopathies (M53), back pain / dorsalgia (back disorders without radiation: M54.1, M54.2, M54.3, M54.4, M54.5, M54.6, M54.8, M54.9), and lumbar disc herniation or sciatica (M51.1, M51.2, M54.3, and M54.4). *Upper extremity disorders* included any of the following diseases, surgeries or treatments: carpal tunnel syndrome, carpal tunnel release (G56.0, ACC51, ACC59), shoulder disorder (M75), medial epicondylitis, lateral epicondylitis, and periarthritis of wrist (M77.0, M77.1, M77.2, or M77.3). Additionally, the numbers of visits due to osteoarthritis (M15, M16, M17, M18) were examined, but found to be too low for statistical analyses (see Table 1).

Covariates

From the questionnaires we obtained information on possible confounders. We included sex and age at wave 1, and parental occupational status in childhood (1=upper non-manual, 2=lower non-manual, 3=upper manual, 4=lower manual). Smoking (ever smoker vs. non-smoker) and body mass index (BMI, kg/m^2 based on measured weight and height) were included as time varying covariates collected at baseline, 2001, 2007 and 2011. Measure for physical activity (PA) was based on a set of questions requesting the frequency and intensity of PA, frequency of vigorous PA, hours spent on vigorous PA, average duration of a PA session, and participation in organized PA. Based on these questions a *physical activity index* was calculated (range 5-15, larger value indicating greater activity).[15] For PA, we used the maximum of the three measurements of the PA index in adulthood (2001, 2007 and 2011), as these data had plenty of missing values, but the patterns of PA have been observed to remain constant in adulthood.[16] Missing data on covariates were imputed using mean of the study sample in the corresponding survey. All these covariates have been linked to back problems in prior studies.[11 17-19]

Statistical analyses

We used generalized estimating equation models with Poisson distribution to assess associations between the five-class physical work exposure, "no exposure" serving as the reference group, and primary health care visits due to MSD. We ran models separately for all musculoskeletal visits, for disorders of the spine, and for upper extremity disorders. Two model specifications were used: Model 1 was adjusted for sex and age at baseline, Model 2 was additionally adjusted for parental occupational class and time-varying smoking, BMI and physical activity. Results are presented as risk ratios (RR) with 95% confidence intervals (CI). As an alternative method, we ran the analyses using Cox proportional models, which resulted in very similar findings (data not shown).

Results

Descriptive statistics of the analysis sample in total and by sex are shown in Table 1. At baseline, mean age was 20.5 (SD=2.9) years, and mean BMI 22.4 (SD=2.3), while the mean BMI during the follow-up was 25.5 (SD=4.8). Mean follow-up time for first visits due to any MSD was 3.2 (SD=0.87) years, due to spine disorders 3.4 (SD=0.63) years, and due to upper extremity disorders 3.4 (SD=0.50) years. Distributions of the outcomes and proportions of events in each of the five exposure groups in total and by sex are presented in Table 2. As shown in Table 2, the low numbers of events prevented sex-specific analyses.

Associations between physical heaviness of work and primary health care visits due to the three outcome groups are presented in Table 3. Overall, the age- and sex-adjusted estimates (Model 1) were slightly attenuated after including parental occupational status smoking, BMI and physical activity (Model 2). We observed an association between early exposure only and any musculoskeletal disorders (fully adjusted RR 1.55, 95% CI 1.05−2.28) and a slightly weaker association for later exposure only (RR 1.46, 95% 1.01−2.12). Early and later exposure had the strongest association with any visits due to MSD (RR 1.99, 95% CI 1.44−2.77).

For disorders of the spine, we observed an association for later exposure only (RR 2.40, 95% CI 1.41−4.06), inconsistent exposure (RR 2.30, 95% CI 1.34−3.95), and early and later exposure (RR 2.43, 95% CI 1.42−4.14). Effect estimates for visits due to upper extremity disorders were also positive, that for early and later exposure (HR 3.97, 95% CI 1.86−8.46) reaching statistical significance, although with a wide confidence interval.

Discussion

In this study, reporting both early and later exposure to heavy physical work was associated with objectively measured MSDs requiring primary health care visit in midlife. In addition, physical heaviness of work in early adulthood only was associated with an increased risk of primary health care visit due to any MSD, and exposure in later adulthood only was associated with any MSD and disorders of the spine. These diagnosis-specific findings are in line with our prior findings for self-reported low back pain.[8] Although our current analyses may have lacked power to detect precise associations, particularly for upper extremity disorders, the findings suggest that physical work exposure is also a predictor of objectively measured MSDs even after considering behavioural factors and parental socioeconomic position.

Longitudinal studies on the associations between physical work exposures and objectively measured MSDs are scarce. Specifically, we are not aware of studies that would have collected and used data on work-related physical exposures of participants from early to later adulthood, and health care visits due to MSDs in midlife. Some evidence exists regarding physical work exposures and musculoskeletal pain or disorders at an early stage of the working career. In one cross-sectional study repetitive and asymmetric demands, including high probability of repetitive tasks, bending or rotation movements and manual materials handling, was associated with the presence of neck/shoulder pain and severity of upper- and lower-back pain among 21-year-old employees.[20] Another cross-sectional study among less than 30-year-old employees reported similar results regarding the association between physical work exposures (e.g. repetitive flexion or rotation movements of the trunk, and more than three years in a job including lifting more than 25 kg at least once an hour) and low back pain.[21] However, in these studies follow-up for mid-life musculoskeletal disorders was not available. Timing of outcome measurement seems essential as it is likely that there are differences in associations between physical work and MSD among 20-35, 36-49 and over 50-year old employees.[22]

Several studies have reported associations between physical work exposures and increased risk of objectively measured disability retirement due to MSD.[5 23-25] However, only one of these studies examined how exposure in early adulthood was associated with disability retirement due to MSD in mid-life.[25] Moreover, only a few studies have reported associations between cumulative exposure to physical work throughout the work career and objectively measured sickness absence or disability retirement in general,[26] or due to disability retirement due to MSD in particular.[6] These findings have been in line with ours, although the cumulative exposure in the study focusing on MSD was assessed using a job exposure matrix.

Some limitations of this study need to be acknowledged. We used self-reported assessment of physical heaviness of work that was based on a single question. Consequently, the specificity of the exposure, e.g. regarding exposure of different parts of the body, is low. Although such questions have widely been used in epidemiological studies and have indicated good validity,[27] this may partly explain the non-significant associations between physical work and upper extremity disorders. We cannot rule out the possibility of changes in the exposure or outcomes between the survey waves, however, the long follow-up enabled us to examine the long-term consequences of early and later physical work and midlife musculoskeletal health problems that were objectively measured. It can be speculated that primary health care visits with musculoskeletal diagnosis among the middle aged are mostly a result of pain complaints. Severe pain may interfere with work activities and induce need for sickness absence, which may be the primary motivation for the visit to a physician. Thus, the used outcomes may reflect the severity of work disability due to musculoskeletal pain. The follow-up period for the outcomes was neither very long; however, the major strength of this work is the prospective study design with three repeated assessments of physical heaviness of work that were initiated already in early adulthood. Moreover, the used cohort data were representative of the general population with relatively little loss to follow-up.[13] This suggests good generalizability to the Finnish working population, while more caution is needed when assessing generalizability to other countries with different health care systems.

In summary, our findings suggest that exposure to heavy physical work over the work career contributes to the high burden in the health care. Therefore, preventive actions against musculoskeletal problems due to physically heavy work in early adulthood, later adulthood and cumulatively throughout the work career are needed. One possible action, specifically among young employees, might be good introduction to ergonomic ways to work. Guidance on how to recover from physical work tasks is also important; for example, at individual level recovery training has been seen beneficial to the employees.[28] At organizational level, procedures enabling recovery during the work day could include task variation and convenient work-break schedules,[28] which are likely to be applicable throughout the work career.

A competing interest declaration

All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare that (1) JIH and TLa have support from the Academy of Finland; (2) JIH and TLa have no relationships with the Finnish Academy that might have an interest in the submitted work in the previous 3 years; (3) their spouses, partners, or children have no financial relationships that may be relevant to the submitted work; and (4) JIH, RS, HS, MM, SS, EV-J, MK, TLe, OR and TLa have no non-financial interests that may be relevant to the submitted work.

Authors' contributions JIH, RS, MM, HS, EV-J, SS and TLa conceived and designed the experiments, TLa analysed the data, JIH wrote the first draft of the article, MK, TLe and OR contributed materials and/or analysis tools. TLa, MK, TLe and OR contributed to the funding of the study. TLa is the guarantor of the study. All authors were involved in interpretation of the findings, writing the paper and approved the submitted and published versions.

Funding The research was funded by the Finnish Academy (grant numbers 287488 and 319200 for TLa and JIH). The Young Finns Study has been financially supported by the

Academy of Finland: grants 286284, 134309 (Eye), 126925, 121584, 124282, 129364, 129378 (Salve), 117787 (Gendi), and 41071 (Skidi); the Social Insurance Institution of Finland; Competitive State Research Financing of the Expert Responsibility area of Kuopio, Tampere and Turku University Hospitals (grant X51001); Juho Vainio Foundation; Paavo Nurmi Foundation; Finnish Foundation for Cardiovascular Research; Finnish Cultural Foundation; The Sigrid Juselius Foundation; Tampere Tuberculosis Foundation; Emil Aaltonen Foundation; Yrjö Jahnsson Foundation; Signe and Ane Gyllenberg Foundation; Diabetes Research Foundation of Finnish Diabetes Association; and EU Horizon 2020 (grant 755320 for TAXINOMISIS); and European Research Council (grant 742927 for MULTIEPIGEN project); Tampere University Hospital Supporting Foundation.

Ethics approval The study has received ethical approval from the Ethics Committee of the Hospital District of Southwest Finland on September 21st, 2010.

Data sharing No additional data available

Acknowledgements The authors thank statistician Niina Kartiosuo for her help with the formation of the analysis dataset.

Figure Legend

Figure 1. Study design.

References

1 OECD. Sickness, Disability and Work: Breaking the Barriers. A Synthesis of Findings across OECD Countries OECD Publishing, Paris. 2010.

2 Linaker C, Harris EC, Cooper C, Coggon D, Palmer KT. The burden of sickness absence from musculoskeletal causes in Great Britain. *Occup Med (Lond)* 2011;61:458-64.

3 Statistics Finland. Recipients of disability pension 2018.

4 Bevan S. Economic impact of musculoskeletal disorders (MSDs) on work in Europe. *Best Pract Res Clin Rheumatol* 2015;29:356-73.

5 Foss L, Gravseth HM, Kristensen P et al. The impact of workplace risk factors on long-term musculoskeletal sickness absence: a registry-based 5-year follow-up from the Oslo health study. *J Occup Environ Med* 2011;53:1478-82.

6 Ervasti J, Pietilainen O, Rahkonen O et al. Long-term exposure to heavy physical work, disability pension due to musculoskeletal disorders and all-cause mortality: 20-year follow-up-introducing Helsinki Health Study job exposure matrix. *Int Arch Occup Environ Health* 2018.

7 Madsen IEH, Gupta N, Budtz-Jorgensen E et al. Physical work demands and psychosocial working conditions as predictors of musculoskeletal pain: a cohort study comparing self-reported and job exposure matrix measurements. *Occup Environ Med* 2018;75:752-758.

8 Lallukka T, Viikari-Juntura E, Viikari J et al. Early work-related physical exposures and low back pain in midlife: the Cardiovascular Risk in Young Finns Study. *Occup Environ Med* 2017;74:163-168.

9 Kjellberg K, Lundin A, Falkstedt D, Allebeck P, Hemmingsson T. Long-term physical workload in middle age and disability pension in men and women: a follow-up study of Swedish cohorts. *Int Arch Occup Environ Health* 2016;89:1239-1250.

10 Sundstrup E, Hansen AM, Mortensen EL et al. Retrospectively assessed physical work environment during working life and risk of sickness absence and labour market exit among older workers. *Occup Environ Med* 2018;75:114-123.

11 Lallukka T, Viikari-Juntura E, Raitakari OT et al. Childhood and adult socio-economic position and social mobility as determinants of low back pain outcomes. *Eur J Pain* 2014;18:128-38.

12 Power C, Atherton K, Strachan DP et al. Life-course influences on health in British adults: effects of socio-economic position in childhood and adulthood. *Int J Epidemiol* 2007;36:532-9.

13 Raitakari OT, Juonala M, Ronnemaa T et al. Cohort profile: the cardiovascular risk in Young Finns Study. *Int J Epidemiol* 2008;37:1220-6.

14 National Institute for Health and Welfare. Register of Primary Health Care visits, Helsinki: National Institute for Health and Welfare 2019.

15 Rovio SP, Yang X, Kankaanpaa A et al. Longitudinal physical activity trajectories from childhood to adulthood and their determinants: The Young Finns Study. *Scand J Med Sci Sports* 2018;28:1073-1083.

16 Telama R, Yang X, Leskinen E et al. Tracking of physical activity from early childhood through youth into adulthood. *Med Sci Sports Exerc* 2014;46:955-62.

17 Shiri R, Karppinen J, Leino-Arjas P, Solovieva S, Viikari-Juntura E. The association between smoking and low back pain: a meta-analysis. *Am J Med* 2010;123:87.e7-35.

18 -. The association between obesity and low back pain: a meta-analysis. *Am J Epidemiol* 2010;171:135-54.

19 Shiri R, Euro U, Heliovaara M et al. Lifestyle Risk Factors Increase the Risk of Hospitalization for Sciatica: Findings of Four Prospective Cohort Studies. *Am J Med* 2017;130:1408-1414.e6.

20 Lourenco S, Araujo F, Severo M, Cunha Miranda L, Carnide F, Lucas R. Patterns of biomechanical demands are associated with musculoskeletal pain in the beginning of professional life: a population-based study. *Scand J Work Environ Health* 2015;41:234-46.

21 Van Nieuwenhuyse A, Fatkhutdinova L, Verbeke G et al. Risk factors for first-ever low back pain among workers in their first employment. *Occup Med (Lond)* 2004;54:513-9.
22 Oakman J, Neupane S, Nygard CH. Does age matter in predicting musculoskeletal disorder risk? An analysis of workplace predictors over 4 years. *Int Arch Occup Environ Health* 2016;89:1127-36.
23 Lahelma E, Laaksonen M, Lallukka T et al. Working conditions as risk factors for disability retirement: a longitudinal register linkage study. *BMC Public Health* 2012;12:309.
24 Robroek SJW, Jarvholm B, van der Beek AJ, Proper KI, Wahlstrom J, Burdorf A. Influence of obesity and physical workload on disability benefits among construction workers followed up for 37 years. *Occup Environ Med* 2017;74:621-627.
25 Ropponen A, Svedberg P, Koskenvuo M, Silventoinen K, Kaprio J. Physical work load and psychological stress of daily activities as predictors of disability pension due to musculoskeletal disorders. *Scand J Public Health* 2014;42:370-6.
26 Sundstrup E, Hansen AM, Mortensen EL et al. Cumulative occupational mechanical exposures during working life and risk of sickness absence and disability pension: prospective cohort study. *Scand J Work Environ Health* 2017;43:415-425.
27 Stock SR, Fernandes R, Delisle A, Vezina N. Reproducibility and validity of workers' self-reports of physical work demands. *Scand J Work Environ Health* 2005;31:409-37.
28 Verbeek J, Ruotsalainen J, Laitinen J et al. Interventions to enhance recovery in healthy workers; a scoping review. *Occup Med (Lond)* 2018.

Table 1. Descriptive statistics of the study population at baseline, percentages (%).

Variable (N missing)	All N_{obs}=5850	Men N_{obs}=2490	Women N_{obs}=3360
	%	%	%
Parental occupational status (125)			
upper non-manual	14	15	14
lower non-manual	42	40	44
upper manual	27	28	26
lower manual	17	17	16
Ever smokers (-)	46	51	46
Low physical activity index* (30)	67	67	67
Cumulative exposure to heavy physical work (-)			
No exposure	49	37	58
Early exposure only	12	16	8
Later exposure only	13	10	15
Inconsistent exposure	11	11	11
Early and later exposure	15	26	8
Outcomes (-)			
Any musculoskeletal disease	21	17	24
Disorders of the spine	10	8	11
Upper extremity disorders	5	4	6
Osteoarthritis	1.4	0.8	1.8

* Index score 5-10

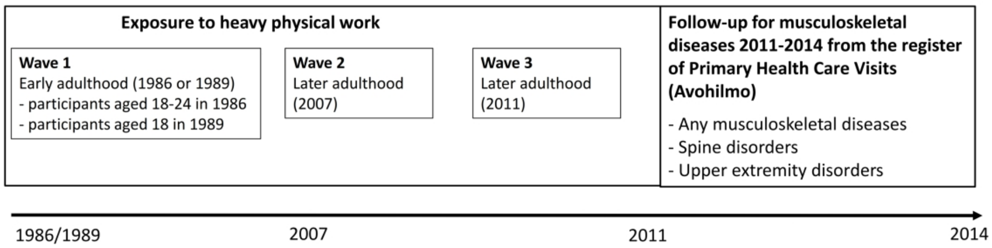
Table 2. Number of observations and proportions (%) of primary health care visits due to musculoskeletal diseases by the exposure categories for physical heaviness of work between 2011 and 2014.

Physical heaviness of work	Any musculoskeletal disease N_{obs} (%)	Disorders of the spine N_{obs} (%)	Upper extremity disorders N_{obs} (%)	Osteroarthritis N_{obs} (%)
All	1120	540	265	80
No exposure	420 (37)	175 (32)	70 (26)	45 (0.8)
Early exposure	140 (12)	65 (12)	35 (13)	20 (0.4)
Later exposure	165 (15)	105 (19)	45 (17)	5 (0.1)
Inconsistent exposure	175 (16)	85 (16)	35 (13)	10 (0.2)
Early and later exposure	220 (20)	110 (20)	80 (30)	0 (0)
Men	745	360	170	60
No exposure	340 (46)	105 (42)	50 (29)	35 (58)
Early exposure	60 (8)	30 (8)	15 (9)	15 (25)
Later exposure	110 (15)	65 (18)	30 (18)	5 (8)
Inconsistent exposure	130 (18)	55 (15)	35 (21)	5 (8)
Early and later exposure	105 (14)	60 (17)	40 (23)	0 (0)
Women	375	180	95	20
No exposure	80 (21)	25 (14)	20 (21)	10 (50)
Early exposure	80 (21)	35 (19)	20 (21)	5 (25)
Later exposure	55 (15)	40 (22)	15 (16)	0 (0)
Inconsistent exposure	45 (12)	30 (17)	0 (0)	5 (25)
Early and later exposure	115 (31)	50 (28)	40 (42)	0 (0)

Table 3. Risk ratios for primary health care visits due to musculoskeletal diseases in relation to early and later exposure to heavy physical work.

	Model 1*			Model 2†		
Physical heaviness of work	RR	95% CI		RR	95% CI	
Any musculoskeletal disease						
No exposure	1			1		
Early exposure	1.65	1.12	2.41	1.55	1.05	2.28
Later exposure	1.55	1.08	2.22	1.46	1.01	2.12
Inconsistent exposure	1.94	1.39	2.72	1.87	1.34	2.61
Early and later exposure	2.12	1.53	2.93	1.99	1.44	2.77
Disorders of the spine						
No exposure	1			1		
Early exposure	1.88	1.03	3.43	1.76	0.96	3.22
Later exposure	2.48	1.49	4.14	2.40	1.41	4.06
Inconsistent exposure	2.31	1.34	3.98	2.30	1.34	3.95
Early and later exposure	2.61	1.55	4.39	2.43	1.42	4.14
Upper extremity disorders						
No exposure	1			1		
Early exposure	2.51	1.03	6.12	2.16	0.87	5.37
Later exposure	2.30	0.99	5.38	2.02	0.85	4.85
Inconsistent exposure	2.32	0.96	5.65	2.26	0.94	5.43
Early and later exposure	4.77	2.26	10.1	3.97	1.86	8.46

* Model 1 adjusted for age and sex
† Model 2 adjusted for age, sex, smoking, BMI, physical activity and parental occupational class



289x80mm (300 x 300 DPI)

STROBE Statement— Halonen JI et al. Exposure to heavy physical work from early to later adulthood and primary health care visits due to musculoskeletal diseases in midlife: a register linked study

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **SEE Abstract on p. 3**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **SEE p. 3**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **SEE p. 4**
Objectives	3	State specific objectives, including any pre-specified hypotheses **SEE p. 5**
Methods		
Study design	4	Present key elements of study design early in the paper **SEE p. 5**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **SEE pp. 5-8**
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up **SEE pp. 5-7**
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed **NA**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **SEE pp. 6-8**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **SEE pp. 5-8**
Bias	9	Describe any efforts to address potential sources of bias **SEE p. 8 (covariate adjustments and alternative analysis method)**
Study size	10	Explain how the study size was arrived at **SEE p. 5**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **SEE pp. 5-8**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding **SEE p. 8**
		(*b*) Describe any methods used to examine subgroups and interactions **SEE p. 8**
		(*c*) Explain how missing data were addressed **Missing data were imputed, see p. 7-8**
		(*d*) If applicable, explain how loss to follow-up was addressed **NA**
		(*e*) Describe any sensitivity analyses **SEE p. 8**
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **SEE p. 5 and Table 1**
		(b) Give reasons for non-participation at each stage **NA**
		(c) Consider use of a flow diagram **No flow diagram, inclusion criteria explained on page 5**

Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **SEE pp. 8-9, Table 1**
		(b) Indicate number of participants with missing data for each variable of interest **SEE Table 1.**
		(c) Summarise follow-up time (eg, average and total amount) **see p. 8**
Outcome data	15*	Report numbers of outcome events or summary measures over time **SEE Table 2.**
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included **SEE Table 3**
		(*b*) Report category boundaries when continuous variables were categorized **See pp. 5-7**
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period **NA**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses **SEE p. 8**
Discussion		
Key results	18	Summarise key results with reference to study objectives **SEE p. 9**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **SEE pp. 10-11**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **SEE pp. 9-11**
Generalizability	21	Discuss the generalizability (external validity) of the study results **SEE p. 11**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **SEE pp. 12-13**

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

BMJ Open

Exposure to heavy physical work from early to later adulthood and primary health care visits due to musculoskeletal diseases in midlife: a register linked study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-031564.R1
Article Type:	Research
Date Submitted by the Author:	04-Jul-2019
Complete List of Authors:	Halonen, Jaana; Finnish Institute of Occupational Health Shiri, Rahman; Finnish Institute of Occupational Health, Centre of Expertise for Health and Work Abili Mänty, Minna; University of Helsinki, Department of Public Health Sumanen, Hilla; South-Eastern Finland University of Applied Sciences, Health care and emergency care; University of Helsinki, Public Health Solovieva, Svetlana; Finnish Institute of Occupational Health, Center of Expertice for Health and workability Viikari-Juntura, Eira; Finnish Institute of Occupational Health, Kahonen, Mika; University of Tampere , Department of Clinical Physiology; Tampere University Hospital Lehtimaki, Terho Raitakari, Olli; University of Turku, Research Centre of Applied and Preventive Cardiovascular Medicine; Turku University Hospital, Department of Clinical Physiology and Nuclear Medicine Lallukka, Tea; Tyoterveyslaitos, ; Helsingin Yliopisto Laaketieteellinen tiedekunta, Department of Public Health
Primary Subject Heading:	Occupational and environmental medicine
Secondary Subject Heading:	Epidemiology
Keywords:	Musculoskeletal disorders < ORTHOPAEDIC & TRAUMA SURGERY, Physical work, Spine < ORTHOPAEDIC & TRAUMA SURGERY, Upper extremity, OCCUPATIONAL & INDUSTRIAL MEDICINE

Research article: BMJ Open

Exposure to heavy physical work from early to later adulthood and primary health care visits due to musculoskeletal diseases in midlife: a register linked study

Jaana I. Halonen,[1] Rahman Shiri,[1] Minna Mänty,[2,3] Hilla Sumanen,[3,4] Svetlana Solovieva,[1] Eira Viikari-Juntura,[1] Mika Kähönen,[5] Terho Lehtimäki,[6] Olli T. Raitakari,[7,8,9] Tea Lallukka[1,3]

1 Finnish Institute of Occupational Health, Helsinki, Finland
2 City of Vantaa, Finland
3 Department of Public Health, University of Helsinki, Helsinki, Finland
4 South-Eastern Finland University of Applied Sciences, Kotka, Finland
5 Department of Clinical Physiology, Tampere University Hospital, and Finnish Cardiovascular Research Center - Tampere, Faculty of Medicine and Health Technology, Tampere University, Tampere 33521, Finland
6 Department of Clinical Chemistry, Fimlab Laboratories, and Finnish Cardiovascular Research Center - Tampere, Faculty of Medicine and Health Technology, Tampere University, Tampere 33520, Finland
7 Centre for Population Health Research, University of Turku and Turku University Hospital, Turku, Finland.
8 Research Centre of Applied and Preventive Cardiovascular Medicine, University of Turku, Turku, Finland.
9 Department of Clinical Physiology and Nuclear Medicine, Turku University Hospital, Turku, Finland.

Corresponding author: Jaana I. Halonen, address: Finnish Institute of Occupational Health, 70032 TYÖTERVEYSLAITOS, Finland

E-mail: jaana.halonen@ttl.fi Telephone: +358 43 82 44 264

Running title Physical work from early to later adulthood and musculoskeletal visits

Word count 2784

Abstract (280/300)

Objectives: To examine whether exposure to heavy physical work from early to later adulthood is associated with primary health care visits due to cause-specific musculoskeletal diseases in midlife.

Design: Prospective cohort study

Setting: Nationally representative Young Finns Study cohort, Finland.

Participants: 1056 participants of the Young Finns Study cohort.

Exposure measure: Physical work exposure was surveyed in early (18–24 years old, 1986 or 1989) and later adulthood (2007 and 2011), and it was categorized as: "no exposure", "early exposure only", "later exposure only", and "early and later exposure".

Primary and secondary outcome measures: Visits due to any musculoskeletal disease and separately due to spine disorders, and upper extremity disorders were followed-up from national primary health care register from the date of the third survey in 2011 until 2014.

Results: Prevalence of any musculoskeletal disease during the follow-up was 20%, that for spine disorders 10%, and that for upper extremity disorders 5%. Those with physically heavy work in early adulthood only had an increased risk of any musculoskeletal disease (risk ratio (RR) 1.55, 95% confidence interval (CI) 1.05−2.28) after adjustment for age, sex, smoking, body mass index, physical activity, and parental occupational class. Later exposure only was associated with visits due to any musculoskeletal disease (RR 1.46, 95% CI 1.01−2.12) and spine disorders (RR 2.40, 95% CI 1.41−4.06). Early and later exposure was associated with all three outcomes: RRs 1.99 (95% CI 1.44−2.77) for any musculoskeletal disease, 2.43 (95% CI 1.42−4.14) for spine disorders, and 3.97 (95% CI 1.86−8.46) for upper extremity disorders.

Conclusions: To reduce burden of musculoskeletal diseases, preventive actions to reduce exposure to or mitigate the consequences of physically heavy work throughout the work career are needed.

Key words: musculoskeletal; physical work; spine disorder; upper extremity

Strengths and limitations of this study

- We used self-reported assessment of physical heaviness of work that was based on a single question, which is why the specificity of the exposure, e.g. regarding exposure of different parts of the body, is low.
- We cannot rule out the possibility of changes in the exposure or outcomes between the survey waves.
- The setting enabled us to prospectively examine the long-term consequences of exposure to early and later physical work and midlife musculoskeletal health problems that were objectively measured.
- The used cohort data were representative of the general population with relatively little loss to follow-up.

Introduction

Musculoskeletal diseases (MSD) are, along with mental disorders, the leading cause of work disability[1] measured as sickness absence[2] and disability retirements.[3] In the European Union, the estimated total cost of lost productivity attributable to MSD among working-aged people can be up to 2% of gross domestic product (GDP).[4] Contextual factors, particularly those related to workplace, have been identified as risk factors for sickness absence and disability retirement due to musculoskeletal problems[5 6] as well as for musculoskeletal pain.[7] We have reported findings where early and cumulative exposure to physical work were associated with low back pain at midlife.[8] However, pain as an outcome is always self-reported, as well as a common condition. Thus, objective outcome measures are needed to confirm whether the effects of early and cumulative physical work are similar for more severe and objectively assessed MSD outcomes.

Only few studies to date have been able to assess the associations between cumulative exposure to physical work and MSD. A recent study used a job exposure matrix to assess exposure at the level of occupational title and disability retirement due to MSD,[6] but even the first exposure measurements were mainly from midlife. In another study, two individual-level measurements were used to examine the associations between long-term exposure to high physical workload in midlife and risk of disability retirement due to MSD after age of 61,[9] while younger employees were not included. Yet another study used individual-level physical work exposure data that were retrospectively assessed, and observed that cumulative exposure may increase the risk of sickness absence and disability retirement, but results for cause-specific outcomes were not reported.[10] In addition to the lack of cumulative exposure data, prior studies have rarely accounted for family background although parental socioeconomic position has been linked, for example, to later musculoskeletal problems[11] and widespread pain[12] as well as career possibilities[13] and choices.[14]

To fill these gaps in evidence, we examined whether physical heaviness of work from early adulthood to later adulthood is associated with primary health care visits due to MSD in midlife. We hypothesized that early, later and repeated exposure to heavy work is associated with later health care visits. Any MSD was examined as one outcome group, but we also included two cause-specific groups: disorders of the spine and upper extremities. The contribution of behavioural factors and parental socioeconomic position in these associations were considered.

Methods

Participants

Data for this study are derived from the Young Finns Study.[15] Cohort baseline data were collected in 1980 in six age strata: 3, 6, 9, 12, 15, and 18 years resulting in 3596 participants (response rate 83%). For this study, we included all those who were 18, 21 or 24 years when responding to the survey in 1986 (early adulthood). These data were completed by including also those who turned 18 years and responded to the survey in 1989 (**Figure 1**.). The age-based selection criterion was applied as the focus of this study was on early work-related exposures. Further inclusion criterion required that the participants responded to the question on physical heaviness of work in 1986 or 1989 (early adulthood exposure, N=1119), and in 2007 (later adulthood exposure, N=1090) and/or in 2011 (later adulthood exposure, N=1042), which resulted in a total of 10854 participants. After excluding those with missing data on any covariate (after re-coding and imputation), the final study sample was 1056 cohort participants (with 5171 observations) who all had work exposure measurement from early adulthood and at least one measurement from later adulthood. The study has been ethically approved by the Ethics Committee of the Hospital District of Southwest Finland.

Patient and Public Involvement statement

Patients or the public were not involved in the development of the research question or the design of this study nor in the conduct of the study.

Exposure

Physical heaviness of work was enquired at waves 1 to 3 with a single question: “How heavy is your work physically?”. There were six response alternatives: 1) light sedentary work, 2) other sedentary work, 3) physically light work, involving standing and moving, 4) medium heavy work involving moving, 5) physically heavy work, and 6) physically very heavy work. The responses were categorized as: sedentary/physically light work, and medium to heavy physical work. We used responses from all three waves to form a five-class exposure variable categorized as: “no exposure”, when reporting sedentary/physically light work in all three waves, “early exposure only”, when reporting medium to heavy physical work only in wave 1, “later exposure only”, when reporting medium to heavy physical work in waves 2 or 3 (89% responded to both waves 2 and 3), and “early and later exposure” when reporting medium to heavy physical work in wave 1 and in later adulthood in wave 2 and/or 3. All other possible response combinations formed a group “inconsistent exposure”.

Outcomes

We examined primary health care visits due to a musculoskeletal diagnosis. The follow-up started from the day after returning wave 3 survey in 2011. Repeated visits were used for the main analyses. For an alternative analysis, time to the first visit was used as an outcome, and the follow-up from returning the survey in 2011 continued until the first primary health care visit, death (from Statistics Finland) or end of the follow-up (end of 2014), whichever occurred first. Data were obtained from the register of primary health care visits (Avohilmo) maintained by National Institute for Health and Welfare.[16] Diagnosis-specific data have been collected and were available from 2011 onwards. Visits due to *any musculoskeletal diagnosis* by International Classification of Diseases (ICD) version 10 codes M00-M99 were examined over the follow-up period. Additionally, two cause-specific outcome groups with the largest numbers of events were: 1) disorders of the spine and 2) upper extremity disorders. *Disorders of the spine* included any of the following diseases, surgeries or treatments (ICD-10 code): cervical disc disorders (M50), lumbar and other intervertebral disc disorders with radiculopathy (M51.1), other specified intervertebral disc displacement (M51.2), disc degeneration (M51.3), disc disorders (M51.8), intervertebral disc disorder, unspecified (M51.9), disc disorder/ disc disease (back disorders with radiation: M50, M51), other dorsopathies (M53), back pain / dorsalgia (back disorders without radiation: M54.1, M54.2, M54.3, M54.4, M54.5, M54.6, M54.8, M54.9), and lumbar disc herniation or sciatica (M51.1, M51.2, M54.3, and M54.4). *Upper extremity disorders* included any of the following diseases, surgeries or treatments: carpal tunnel syndrome, carpal tunnel release (G56.0, ACC51, ACC59), shoulder disorder (M75), medial epicondylitis, lateral epicondylitis, and periarthritis of wrist (M77.0, M77.1, M77.2, or M77.3). Additionally, the numbers of visits due to osteoarthritis (M15, M16, M17, M18) were examined, but found to be too low for statistical analyses (see Table 1).

Covariates

From the questionnaires we obtained information on possible confounders. We included sex and age at wave 1, and parental occupational status in childhood (1=upper non-manual, 2=lower non-manual, 3=upper manual, 4=lower manual). Smoking (ever smoker vs. non-smoker) and body mass index (BMI, kg/m^2 based on measured weight and height) were included as time varying covariates collected at baseline, 2001, 2007 and 2011. Measure for leisure-time physical activity (PA) was based on a set of questions requesting the frequency and intensity of PA, frequency of vigorous PA, hours spent on vigorous PA, average duration of a PA session, and participation in organized PA. Based on these questions a *physical activity index* was calculated (range 5-15, larger value indicating greater activity).[17] For PA, we used the maximum of the three measurements of the PA index in adulthood (2001, 2007 and 2011), as these data had plenty of missing values (N missing =730 in 2001, 150 in 2007 and 475 in 2011), but the patterns of PA have been observed to remain constant in adulthood.[18] Missing data on smoking were re-coded as "non-smoker", and missing data on BMI were imputed using mean of the study sample in the corresponding survey. Although this is not the strongest imputation method we considered it was the most applicable one, as the method only concerned one covariate. All these covariates have been linked to back problems in prior studies[11 19-21] and smoking can be also considered as an indicator of low socioeconomic position, which may affect the choice of employment and further physical workload.

Statistical analyses

We used generalized estimating equation (GEE) models with Poisson distribution to assess associations between the five-class physical work exposure, "no exposure" serving as the reference group, and repeated primary health care visits due to MSD. This method was chosen as the GEE models permit specification of a working correlation matrix that accounts for the form of within-subject correlation of responses on dependent variables of many different distributions, including Poisson.[22] We ran models separately for all musculoskeletal visits, for disorders of the spine, and for upper extremity disorders. Two model specifications were used: Model 1 was adjusted for sex and age at baseline, Model 2 was additionally adjusted for parental occupational class, physical activity, and time-varying smoking and BMI. Results are presented as risk ratios (RR) with 95% confidence intervals (CI). As an alternative method, we ran the analyses using Cox proportional hazard models using time to the first visit as the outcome, which resulted in very similar findings (supplemental Table 1).

Results

Descriptive statistics of the analysis sample in total and by sex are shown in Table 1. At baseline, mean age was 20.5 (SD=2.9) years, and mean BMI 22.4 (SD=2.3), while the mean BMI during the follow-up was 25.5 (SD=4.8). Mean follow-up time for first visits due to any MSD was 3.2 (SD=0.87) years, due to spine disorders 3.4 (SD=0.63) years, and due to upper extremity disorders 3.4 (SD=0.50) years. In the total sample, prevalence of any musculoskeletal disease during the follow-up was 20%, that for spine disorders 10%, and that for upper extremity disorders 5%. Distributions of the outcomes and proportions of events in each of the five exposure groups in total and by sex are presented in Table 2. As shown in Table 2, the low numbers of events prevented sex-specific analyses.

Associations between physical heaviness of work and primary health care visits due to the three outcome groups are presented in Table 3. Overall, the age- and sex-adjusted estimates (Model 1) were slightly attenuated after including parental occupational status smoking, BMI and physical activity (Model 2). We observed an association between early exposure only and any musculoskeletal disorders (fully adjusted RR 1.55, 95% CI 1.05−2.28) and a slightly weaker association for later exposure only (RR 1.46, 95% 1.01−2.12). Early and later exposure had the strongest association with any visits due to MSD (RR 1.99, 95% CI 1.44−2.77).

For disorders of the spine, we observed an association for later exposure only (RR 2.40, 95% CI 1.41−4.06), inconsistent exposure (RR 2.30, 95% CI 1.34−3.95), and early and later exposure (RR 2.43, 95% CI 1.42−4.14). Effect estimates for visits due to upper extremity disorders were also positive, that for early and later exposure (HR 3.97, 95% CI 1.86−8.46) reaching statistical significance, although with a wide confidence interval.

Discussion

In this study, reporting both early and later exposure to heavy physical work was associated with objectively measured MSDs requiring primary health care visit in midlife. In addition, physical heaviness of work in early adulthood only was associated with an increased risk of primary health care visit due to any MSD, and exposure in later adulthood only was associated with any MSD and disorders of the spine. These diagnosis-specific findings are in line with our prior findings for self-reported low back pain.[8] Although our current analyses may have lacked power to detect precise associations, particularly for upper extremity disorders, the findings suggest that physical work exposure is also a predictor of objectively measured MSDs even after considering behavioural factors and parental socioeconomic position.

Longitudinal studies on the associations between physical work exposures and objectively measured MSDs are scarce. Specifically, we are not aware of studies that would have collected and used data on work-related physical exposures of participants from early to later adulthood, and health care visits due to MSDs in midlife. Some evidence exists regarding physical work exposures and musculoskeletal pain or disorders at an early stage of the working career. In one cross-sectional study repetitive and asymmetric demands, including high probability of repetitive tasks, bending or rotation movements and manual materials handling, was associated with the presence of neck/shoulder pain and severity of upper- and lower-back pain among 21-year-old employees.[23] Another cross-sectional study among less than 30-year-old employees reported similar results regarding the association between physical work exposures (e.g. repetitive flexion or rotation movements of the trunk, and more than three years in a job including lifting more than 25 kg at least once an hour) and low back pain.[24] However, in these studies follow-up for mid-life musculoskeletal disorders was not available. Timing of outcome measurement seems essential as it is likely that there are differences in associations between physical work and MSD among 20-35, 36-49 and over 50-year old employees.[25]

Several studies have reported associations between physical work exposures and increased risk of objectively measured disability retirement due to MSD.[5 26-28] However, only one of these studies examined how exposure in early adulthood was associated with disability retirement due to MSD in mid-life.[28] Moreover, only a few studies have reported associations between cumulative exposure to physical work throughout the work career and objectively measured sickness absence or disability retirement in general,[29] or due to disability retirement due to MSD in particular.[6] These findings have been in line with ours, although the cumulative exposure in the study focusing on MSD was assessed using a job exposure matrix.

Some limitations of this study need to be acknowledged. We used self-reported assessment of physical heaviness of work that was based on a single question. Consequently, the specificity of the exposure, e.g. regarding exposure of different parts of the body, is low. Although such questions have widely been used in epidemiological studies and have indicated good validity,[30] this may partly explain the non-significant associations between physical work and upper extremity disorders. We also used a dichotomized physical heaviness of work measure where medium and heavy/very heavy work were combined as the proportion of those with heavy/very heavy work was rather low (10% at early adulthood).

The used cut-off may have attenuated the observed associations if medium heavy work had substantially weaker association with health care visits than heavy/very heavy work. We cannot rule out the possibility of changes in the exposure or outcomes between the survey waves, which may have caused under- or over-estimation of the associations. However, the long follow-up enabled us to examine the long-term consequences of early and later physical work and midlife musculoskeletal health problems that were objectively measured. Some healthy worker effect may have attenuated the findings as we required minimum of two responses (from early and later adulthood) regarding physical heaviness of work and those with physically strenuous work or with musculoskeletal problems may have left employment before the second survey. It can also be speculated that primary health care visits with musculoskeletal diagnosis in midlife are mostly a result of pain complaints. Severe pain may interfere with work activities and induce need for sickness absence, which may be the primary motivation for the visit to a physician. Thus, the used outcomes may reflect the severity of work disability due to a subjective measure of musculoskeletal pain. The follow-up period for the outcomes was not very long and unobserved changes in the exposure or covariates during the outcome follow-up could have caused some bias to the findings resulting in under- or overestimation of the observed associations. However, the major strength of this work is the prospective study design with three repeated assessments of physical heaviness of work that were initiated in early adulthood. Moreover, the used cohort data were representative of the general population with relatively little loss to follow-up.[15] As we used register data, only persons who emigrate will no more have registered health care visits. This suggests good generalizability to the Finnish working population, while more caution is needed when assessing generalizability to other countries with different health care systems.

In summary, our findings suggest that exposure to heavy physical work over the work career contributes to the high burden in the health care. Therefore, preventive actions against musculoskeletal problems due to physically heavy work in early adulthood, later adulthood and cumulatively throughout the work career are needed. One possible action, specifically among young employees, might be good introduction to ergonomic ways to work. Guidance on how to recover from physical work tasks is also important; for example, at individual level recovery training has been seen beneficial to the employees.[31] At organizational level, procedures enabling recovery during the work day could include task variation and convenient work-break schedules,[31] which are likely to be applicable throughout the work career.

A competing interest declaration

All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare that (1) JIH and TLa have support from the Academy of Finland; (2) JIH and TLa have no relationships with the Finnish Academy that might have an interest in the submitted work in the previous 3 years; (3) their spouses, partners, or children have no financial relationships that may be relevant to the submitted work; and (4) JIH, RS, HS, MM, SS, EV-J, MK, TLe, OR and TLa have no non-financial interests that may be relevant to the submitted work.

Authors' contributions JIH, RS, MM, HS, EV-J, SS and TLa conceived and designed the experiments, TLa analysed the data, JIH wrote the first draft of the article, MK, TLe and OR contributed materials and/or analysis tools. TLa, MK, TLe and OR contributed to the funding of the study. TLa is the guarantor of the study. All authors were involved in interpretation of the findings, writing the paper and approved the submitted and published versions.

Funding The research was funded by the Finnish Academy (grant numbers 287488 and 319200 for TLa and JIH). The Young Finns Study has been financially supported by the Academy of Finland: grants 286284, 134309 (Eye), 126925, 121584, 124282, 129364, 129378 (Salve), 117787 (Gendi), and 41071 (Skidi); the Social Insurance Institution of Finland; Competitive State Research Financing of the Expert Responsibility area of Kuopio, Tampere and Turku University Hospitals (grant X51001); Juho Vainio Foundation; Paavo Nurmi Foundation; Finnish Foundation for Cardiovascular Research; Finnish Cultural Foundation; The Sigrid Juselius Foundation; Tampere Tuberculosis Foundation; Emil Aaltonen Foundation; Yrjö Jahnsson Foundation; Signe and Ane Gyllenberg Foundation; Diabetes Research Foundation of Finnish Diabetes Association; and EU Horizon 2020 (grant 755320 for TAXINOMISIS); and European Research Council (grant 742927 for MULTIEPIGEN project); Tampere University Hospital Supporting Foundation.

Ethics approval The study has received ethical approval from the Ethics Committee of the Hospital District of Southwest Finland on September 21st, 2010.

Data sharing TLa had access to an anonymized subset of the data that were used for the analyses. OTR had full access to all raw data. Raw data from the study are not available due to confidentiality and sensitivity issues. Subset of raw data can be requested from OTR olli.raitakari[at]utu.fi.

Acknowledgements The authors thank statistician Niina Kartiosuo for her help with the formation of the analysis dataset.

Figure Legend

Figure 1. Flow chart of the sample selection.

References

1 OECD. Sickness, Disability and Work: Breaking the Barriers. A Synthesis of Findings across OECD Countries OECD Publishing, Paris. 2010.

2 Linaker C, Harris EC, Cooper C, Coggon D, Palmer KT. The burden of sickness absence from musculoskeletal causes in Great Britain. *Occup Med (Lond)* 2011;61:458-64.

3 Statistics Finland. Recipients of disability pension 2018.

4 Bevan S. Economic impact of musculoskeletal disorders (MSDs) on work in Europe. *Best Pract Res Clin Rheumatol* 2015;29:356-73.

5 Foss L, Gravseth HM, Kristensen P et al. The impact of workplace risk factors on long-term musculoskeletal sickness absence: a registry-based 5-year follow-up from the Oslo health study. *J Occup Environ Med* 2011;53:1478-82.

6 Ervasti J, Pietilainen O, Rahkonen O et al. Long-term exposure to heavy physical work, disability pension due to musculoskeletal disorders and all-cause mortality: 20-year follow-up-introducing Helsinki Health Study job exposure matrix. *Int Arch Occup Environ Health* 2018.

7 Madsen IEH, Gupta N, Budtz-Jorgensen E et al. Physical work demands and psychosocial working conditions as predictors of musculoskeletal pain: a cohort study comparing self-reported and job exposure matrix measurements. *Occup Environ Med* 2018;75:752-758.

8 Lallukka T, Viikari-Juntura E, Viikari J et al. Early work-related physical exposures and low back pain in midlife: the Cardiovascular Risk in Young Finns Study. *Occup Environ Med* 2017;74:163-168.

9 Kjellberg K, Lundin A, Falkstedt D, Allebeck P, Hemmingsson T. Long-term physical workload in middle age and disability pension in men and women: a follow-up study of Swedish cohorts. *Int Arch Occup Environ Health* 2016;89:1239-1250.

10 Sundstrup E, Hansen AM, Mortensen EL et al. Retrospectively assessed physical work environment during working life and risk of sickness absence and labour market exit among older workers. *Occup Environ Med* 2018;75:114-123.

11 Lallukka T, Viikari-Juntura E, Raitakari OT et al. Childhood and adult socio-economic position and social mobility as determinants of low back pain outcomes. *Eur J Pain* 2014;18:128-38.

12 Power C, Atherton K, Strachan DP et al. Life-course influences on health in British adults: effects of socio-economic position in childhood and adulthood. *Int J Epidemiol* 2007;36:532-9.

13 Laukkonen M-L. Pienituloisten perheiden ylioppilaat välttävät riskiä pääsykokeita painottavissa opiskelijavalinnoissa [High school graduates from low income families evade risk related to student admission emphasizing entrance examinations]: ETLA 2018.

14 Whiston SC, Keller BK. The Influences of the Family of Origin on Career Development: A Review and Analysis. *The Counceling Psychologist* 2004;32:493-568.

15 Raitakari OT, Juonala M, Rönnemaa T et al. Cohort profile: the cardiovascular risk in Young Finns Study. *Int J Epidemiol* 2008;37:1220-6.

16 National Institute for Health and Welfare. Register of Primary Health Care visits, Helsinki: National Institute for Health and Welfare 2019.

17 Rovio SP, Yang X, Kankaanpaa A et al. Longitudinal physical activity trajectories from childhood to adulthood and their determinants: The Young Finns Study. *Scand J Med Sci Sports* 2018;28:1073-1083.

18 Telama R, Yang X, Leskinen E et al. Tracking of physical activity from early childhood through youth into adulthood. *Med Sci Sports Exerc* 2014;46:955-62.

19 Shiri R, Karppinen J, Leino-Arjas P, Solovieva S, Viikari-Juntura E. The association between smoking and low back pain: a meta-analysis. *Am J Med* 2010;123:87.e7-35.

20 -. The association between obesity and low back pain: a meta-analysis. *Am J Epidemiol* 2010;171:135-54.

21 Shiri R, Euro U, Heliovaara M et al. Lifestyle Risk Factors Increase the Risk of Hospitalization for Sciatica: Findings of Four Prospective Cohort Studies. *Am J Med* 2017;130:1408-1414.e6.
22 Ballinger GA. Using Generalized Estimating Equations for Longitudinal Data Analysis. *Organizational Research Methods* 2004;7:127-150.
23 Lourenco S, Araujo F, Severo M, Cunha Miranda L, Carnide F, Lucas R. Patterns of biomechanical demands are associated with musculoskeletal pain in the beginning of professional life: a population-based study. *Scand J Work Environ Health* 2015;41:234-46.
24 Van Nieuwenhuyse A, Fatkhutdinova L, Verbeke G et al. Risk factors for first-ever low back pain among workers in their first employment. *Occup Med (Lond)* 2004;54:513-9.
25 Oakman J, Neupane S, Nygard CH. Does age matter in predicting musculoskeletal disorder risk? An analysis of workplace predictors over 4 years. *Int Arch Occup Environ Health* 2016;89:1127-36.
26 Lahelma E, Laaksonen M, Lallukka T et al. Working conditions as risk factors for disability retirement: a longitudinal register linkage study. *BMC Public Health* 2012;12:309.
27 Robroek SJW, Jarvholm B, van der Beek AJ, Proper KI, Wahlstrom J, Burdorf A. Influence of obesity and physical workload on disability benefits among construction workers followed up for 37 years. *Occup Environ Med* 2017;74:621-627.
28 Ropponen A, Svedberg P, Koskenvuo M, Silventoinen K, Kaprio J. Physical work load and psychological stress of daily activities as predictors of disability pension due to musculoskeletal disorders. *Scand J Public Health* 2014;42:370-6.
29 Sundstrup E, Hansen AM, Mortensen EL et al. Cumulative occupational mechanical exposures during working life and risk of sickness absence and disability pension: prospective cohort study. *Scand J Work Environ Health* 2017;43:415-425.
30 Stock SR, Fernandes R, Delisle A, Vezina N. Reproducibility and validity of workers' self-reports of physical work demands. *Scand J Work Environ Health* 2005;31:409-37.
31 Verbeek J, Ruotsalainen J, Laitinen J et al. Interventions to enhance recovery in healthy workers; a scoping review. *Occup Med (Lond)* 2018.

Table 1. Descriptive statistics of the study population at baseline.

Variable	All N	All %
Total individuals	1065	100
Women	446	42
Men	610	58
Parental occupational status		
upper non-manual	152	14
lower non-manual	447	42
upper manual	282	27
lower manual	175	17
Ever smokers	516	49
Low physical activity index*	710	67
Cumulative exposure to heavy physical work		
No exposure	523	49
Early exposure only	124	13
Later exposure only	130	12
Inconsistent exposure	118	11
Early and later exposure	161	15
Outcomes (-)		
Any musculoskeletal disease	221	21
Disorders of the spine	107	10
Upper extremity disorders	52	5
Osteoarthritis	16	1.5

* Index score 5-10

Table 2. Number of observations and proportions (%) of primary health care visits due to musculoskeletal diseases by the exposure categories for physical heaviness of work between 2011 and 2014.

Physical heaviness of work	Any musculoskeletal disease N_{obs} (%)	Disorders of the spine N_{obs} (%)	Upper extremity disorders N_{obs} (%)	Osteroarthritis N_{obs} (%)
All	1083	527	253	79
No exposure	405 (37)	168 (32)	66 (26)	44 (56)
Early exposure	137 (13)	64 (12)	34 (13)	20 (25)
Later exposure	156 (14)	102 (19)	40 (16)	5 (6)
Inconsistent exposure	168 (16)	85 (16)	34 (13)	10 (13)
Early and later exposure	217 (20)	108 (21)	79 (31)	0 (0)
Women	730	353	165	59
No exposure	334 (46)	148 (42)	47 (28)	35 (58)
Early exposure	58 (8)	29 (8)	14 (8)	15 (25)
Later exposure	107 (15)	63 (18)	30 (18)	5 (8)
Inconsistent exposure	128 (18)	55 (16)	34 (21)	5 (8)
Early and later exposure	103 (14)	58 (16)	40 (24)	0 (0)
Men	353	174	88	20
No exposure	71 (20)	20 (11)	19 (22)	10 (50)
Early exposure	79 (22)	35 (20)	20 (23)	5 (25)
Later exposure	49 (14)	39 (23)	10 (11)	0 (0)
Inconsistent exposure	40 (11)	30 (17)	0 (0)	5 (25)
Early and later exposure	115 (32)	50 (29)	39 (44)	0 (0)

Table 3. Risk ratios for primary health care visits due to musculoskeletal diseases in relation to early and later exposure to heavy physical work.

	Model 1*			Model 2†		
Physical heaviness of work	RR	95% CI		RR	95% CI	
Any musculoskeletal disease						
No exposure	1			1		
Early exposure	1.65	1.12	2.41	1.55	1.05	2.28
Later exposure	1.57	1.09	2.24	1.46	1.01	2.12
Inconsistent exposure	1.90	1.35	2.67	1.87	1.34	2.61
Early and later exposure	2.14	1.55	2.97	1.99	1.44	2.77
Disorders of the spine						
No exposure	1			1		
Early exposure	1.87	1.02	3.42	1.76	0.96	3.22
Later exposure	2.51	1.51	4.18	2.40	1.41	4.06
Inconsistent exposure	2.32	1.35	3.99	2.30	1.34	3.95
Early and later exposure	2.62	1.56	4.40	2.43	1.42	4.14
Upper extremity disorders						
No exposure	1			1		
Early exposure	2.50	1.03	6.11	2.16	0.87	5.37
Later exposure	2.33	1.00	5.67	2.02	0.85	4.85
Inconsistent exposure	2.33	0.96	5.67	2.26	0.94	5.43
Early and later exposure	4.79	2.28	10.1	3.97	1.86	8.46

* Model 1 adjusted for age and sex

† Model 2 adjusted for age, sex, smoking, BMI, physical activity and parental occupational class

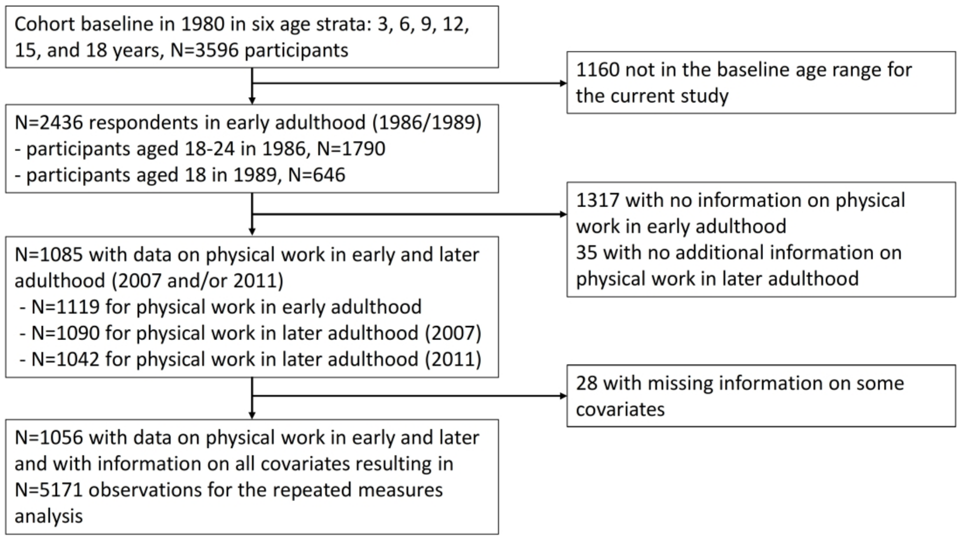


Figure 1. Flow chart of the sample selection.

Supplemental material

Exposure to heavy physical work from early to later adulthood and primary health care visits due to musculoskeletal diseases in midlife: a register linked study

Jaana I. Halonen, Rahman Shiri, Minna Mänty, Hilla Sumanen, Svetlana Solovieva, Eira Viikari-Juntura, Mika Kähönen, Terho Lehtimäki, Olli T. Raitakari, Tea Lallukka

Supplemental Table 1. Associations between early and later exposure to heavy physical work and primary health care visits due to musculoskeletal diseases from Cox proportional hazard models.

	Model 1*			Model 2†		
Physical heaviness of work	HR	95% CI		HR	95% CI	
Any musculoskeletal disease						
No exposure	1			1		
Early exposure	1.95	1.22	3.11	1.90	1.18	3.06
Later exposure	1.36	0.84	2.22	1.32	0.81	2.16
Inconsistent exposure	2.01	1.27	3.17	2.01	1.27	3.17
Early and later exposure	2.41	1.56	3.73	2.26	1.45	3.52
Disorders of the spine						
No exposure	1			1		
Early exposure	2.43	1.17	5.05	2.37	1.14	4.95
Later exposure	2.54	1.30	4.96	2.48	1.26	4.88
Inconsistent exposure	2.36	1.15	4.85	2.38	1.15	4.89
Early and later exposure	3.51	1.81	6.83	3.29	1.67	6.48
Upper extremity disorders						
No exposure	1			1		
Early exposure	3.75	1.28	11.0	3.38	1.14	10.1
Later exposure	2.48	0.80	7.64	2.22	0.72	6.87
Inconsistent exposure	2.46	0.74	8.17	2.27	0.68	7.62
Early and later exposure	6.12	2.33	16.0	4.84	1.81	12.9

* Model 1 adjusted for age and sex
† Model 2 adjusted for age, sex, smoking, BMI, and parental occupational class

STROBE Statement— Halonen JI et al. Exposure to heavy physical work from early to later adulthood and primary health care visits due to musculoskeletal diseases in midlife: a register linked study

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **SEE Abstract on p. 2**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **SEE Abstract on p. 2**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **SEE p. 4**
Objectives	3	State specific objectives, including any pre-specified hypotheses **SEE p. 5**
Methods		
Study design	4	Present key elements of study design early in the paper **SEE p. 5 for description of the study cohort**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **SEE pp. 5-6 (setting), 6 (exposure), 6-7 (outcomes and follow-up)**
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up **SEE p. 5**
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed **NA**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **SEE pp. 6 (exposure), 6-7 (outcome), 8 (covariates)**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **SEE pp. 5 (setting), 6 (exposure), 6-7 (outcomes), 8 (covariates)**
Bias	9	Describe any efforts to address potential sources of bias **SEE pp. 8-9 (covariate adjustments and alternative analysis method)**
Study size	10	Explain how the study size was arrived at **SEE p. 5 and Figure 1 (flow chart)**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **SEE pp. 6 (exposure), 6-7 (outcomes), 8 (covariates)**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding **SEE pp. 8-9**
		(*b*) Describe any methods used to examine subgroups and interactions **SEE pp. 8-9**
		(*c*) Explain how missing data were addressed **SEE p. 8 (covariates)**
		(*d*) If applicable, explain how loss to follow-up was addressed **NA**
		(*e*) Describe any sensitivity analyses **SEE p. 9**

Results

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **SEE p. 5 and Figure 1**
		(b) Give reasons for non-participation at each stage **NA**
		(c) Consider use of a flow diagram **Figure 1 is a flow diagram**
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **SEE p. 9 and Table 1**
		(b) Indicate number of participants with missing data for each variable of interest **Those with missing data were excluded, see page 5 and Figure 1.**
		(c) Summarise follow-up time (eg, average and total amount) **NA**
Outcome data	15*	Report numbers of outcome events or summary measures over time **SEE Table 2.**
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included **SEE Table 3**
		(*b*) Report category boundaries when continuous variables were categorized **See pp. 6 (exposure), 8 (covariates)**
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period **Unadjusted absolute risks provided in the abstract on page 2 and on page 9.**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses **SEE p. 9 and supplemental Table 1.**
Discussion		
Key results	18	Summarise key results with reference to study objectives **SEE p. 10**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **SEE pp. 11-12**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **SEE p. 13**
Generalizability	21	Discuss the generalizability (external validity) of the study results **SEE p. 12**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **SEE p. 14**

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

Exposure to heavy physical work from early to later adulthood and primary health care visits due to musculoskeletal diseases in midlife: a register linked study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-031564.R2
Article Type:	Research
Date Submitted by the Author:	06-Aug-2019
Complete List of Authors:	Halonen, Jaana; Finnish Institute of Occupational Health Shiri, Rahman; Finnish Institute of Occupational Health, Centre of Expertise for Health and Work Abili Mänty, Minna; University of Helsinki, Department of Public Health Sumanen, Hilla; South-Eastern Finland University of Applied Sciences, Health care and emergency care; University of Helsinki, Public Health Solovieva, Svetlana; Finnish Institute of Occupational Health, Center of Expertice for Health and workability Viikari-Juntura, Eira; Finnish Institute of Occupational Health, Kahonen, Mika; University of Tampere , Department of Clinical Physiology; Tampere University Hospital Lehtimaki, Terho Raitakari, Olli; University of Turku, Research Centre of Applied and Preventive Cardiovascular Medicine; Turku University Hospital, Department of Clinical Physiology and Nuclear Medicine Lallukka, Tea; Tyoterveyslaitos, ; Helsingin Yliopisto Laaketieteellinen tiedekunta, Department of Public Health
Primary Subject Heading:	Occupational and environmental medicine
Secondary Subject Heading:	Epidemiology
Keywords:	Musculoskeletal disorders < ORTHOPAEDIC & TRAUMA SURGERY, Physical work, Spine < ORTHOPAEDIC & TRAUMA SURGERY, Upper extremity, OCCUPATIONAL & INDUSTRIAL MEDICINE

Research article: BMJ Open

Exposure to heavy physical work from early to later adulthood and primary health care visits due to musculoskeletal diseases in midlife: a register linked study

Jaana I. Halonen,[1] Rahman Shiri,[1] Minna Mänty,[2,3] Hilla Sumanen,[3,4] Svetlana Solovieva,[1] Eira Viikari-Juntura,[1] Mika Kähönen,[5] Terho Lehtimäki,[6] Olli T. Raitakari,[7,8,9] Tea Lallukka[1,3]

1 Finnish Institute of Occupational Health, Helsinki, Finland
2 City of Vantaa, Finland
3 Department of Public Health, University of Helsinki, Helsinki, Finland
4 South-Eastern Finland University of Applied Sciences, Kotka, Finland
5 Department of Clinical Physiology, Tampere University Hospital, and Finnish Cardiovascular Research Center - Tampere, Faculty of Medicine and Health Technology, Tampere University, Tampere 33521, Finland
6 Department of Clinical Chemistry, Fimlab Laboratories, and Finnish Cardiovascular Research Center - Tampere, Faculty of Medicine and Health Technology, Tampere University, Tampere 33520, Finland
7 Centre for Population Health Research, University of Turku and Turku University Hospital, Turku, Finland.
8 Research Centre of Applied and Preventive Cardiovascular Medicine, University of Turku, Turku, Finland.
9 Department of Clinical Physiology and Nuclear Medicine, Turku University Hospital, Turku, Finland.

Corresponding author: Jaana I. Halonen, address: Finnish Institute of Occupational Health, 70032 TYÖTERVEYSLAITOS, Finland

E-mail: jaana.halonen@ttl.fi Telephone: +358 43 82 44 264

Running title Physical work from early to later adulthood and musculoskeletal visits

Word count 2834

Abstract (280/300)

Objectives: To examine whether exposure to heavy physical work from early to later adulthood is associated with primary health care visits due to cause-specific musculoskeletal diseases in midlife.

Design: Prospective cohort study

Setting: Nationally representative Young Finns Study cohort, Finland.

Participants: 1056 participants of the Young Finns Study cohort.

Exposure measure: Physical work exposure was surveyed in early (18–24 years old, 1986 or 1989) and later adulthood (2007 and 2011), and it was categorized as: "no exposure", "early exposure only", "later exposure only", and "early and later exposure".

Primary and secondary outcome measures: Visits due to any musculoskeletal disease and separately due to spine disorders, and upper extremity disorders were followed-up from national primary health care register from the date of the third survey in 2011 until 2014.

Results: Prevalence of any musculoskeletal disease during the follow-up was 20%, that for spine disorders 10%, and that for upper extremity disorders 5%. Those with physically heavy work in early adulthood only had an increased risk of any musculoskeletal disease (risk ratio (RR) 1.55, 95% confidence interval (CI) 1.05−2.28) after adjustment for age, sex, smoking, body mass index, physical activity, and parental occupational class. Later exposure only was associated with visits due to any musculoskeletal disease (RR 1.46, 95% CI 1.01−2.12) and spine disorders (RR 2.40, 95% CI 1.41−4.06). Early and later exposure was associated with all three outcomes: RRs 1.99 (95% CI 1.44−2.77) for any musculoskeletal disease, 2.43 (95% CI 1.42−4.14) for spine disorders, and 3.97 (95% CI 1.86−8.46) for upper extremity disorders.

Conclusions: To reduce burden of musculoskeletal diseases, preventive actions to reduce exposure to or mitigate the consequences of physically heavy work throughout the work career are needed.

Key words: musculoskeletal; physical work; spine disorder; upper extremity

Strengths and limitations of this study

- We used self-reported assessment of physical heaviness of work that was based on a single question, which is why the specificity of the exposure, e.g. regarding exposure of different parts of the body, is low.
- We cannot rule out the possibility of changes in the exposure or outcomes between the survey waves.
- The setting enabled us to prospectively examine the long-term consequences of exposure to early and later physical work and midlife musculoskeletal health problems that were objectively measured.
- The used cohort data were representative of the general population with relatively little loss to follow-up.

Introduction

Musculoskeletal diseases (MSD) are, along with mental disorders, the leading cause of work disability[1] measured as sickness absence[2] and disability retirements.[3] In the European Union, the estimated total cost of lost productivity attributable to MSD among working-aged people can be up to 2% of gross domestic product (GDP).[4] Contextual factors, particularly those related to workplace, have been identified as risk factors for sickness absence and disability retirement due to musculoskeletal problems[5 6] as well as for musculoskeletal pain.[7] We have reported findings where early and cumulative exposure to physical work were associated with low back pain at midlife.[8] However, pain as an outcome is always self-reported, as well as a common condition. Thus, objective outcome measures are needed to confirm whether the effects of early and cumulative physical work are similar for more severe and objectively assessed MSD outcomes.

Only few studies to date have been able to assess the associations between cumulative exposure to physical work and MSD. A recent study used a job exposure matrix to assess exposure at the level of occupational title and disability retirement due to MSD,[6] but even the first exposure measurements were mainly from midlife. In another study, two individual-level measurements were used to examine the associations between long-term exposure to high physical workload in midlife and risk of disability retirement due to MSD after age of 61,[9] while younger employees were not included. Yet another study used individual-level physical work exposure data that were retrospectively assessed, and observed that cumulative exposure may increase the risk of sickness absence and disability retirement, but results for cause-specific outcomes were not reported.[10] In addition to the lack of cumulative exposure data, prior studies have rarely accounted for family background although parental socioeconomic position has been linked, for example, to later musculoskeletal problems[11] and widespread pain[12] as well as career possibilities[13] and choices.[14]

To fill these gaps in evidence, we examined whether physical heaviness of work from early adulthood to later adulthood is associated with primary health care visits due to MSD in midlife. We hypothesized that early, later and repeated exposure to heavy work is associated with later health care visits. Any MSD was examined as one outcome group, but we also included two cause-specific groups: disorders of the spine and upper extremities. The contribution of behavioural factors and parental socioeconomic position in these associations were considered.

Methods

Participants

Data for this study are derived from the Young Finns Study.[15] Cohort baseline data were collected in 1980 in six age strata: 3, 6, 9, 12, 15, and 18 years resulting in 3596 participants (response rate 83%). For this study, we included all those who were 18, 21 or 24 years when responding to the survey in 1986 (early adulthood). These data were completed by including also those who turned 18 years and responded to the survey in 1989 (**Figure 1**.). The age-based selection criterion was applied as the focus of this study was on early work-related exposures. Further inclusion criterion required that the participants responded to the question on physical heaviness of work in 1986 or 1989 (early adulthood exposure, N=1119), and in 2007 (later adulthood exposure, N=1090) and/or in 2011 (later adulthood exposure, N=1042), which resulted in a total of 10854 participants. After excluding those with missing data on any covariate (after re-coding and imputation), the final study sample was 1056 cohort participants (with 5171 observations) who all had work exposure measurement from early adulthood and at least one measurement from later adulthood. The study has been ethically approved by the Ethics Committee of the Hospital District of Southwest Finland.

Patient and Public Involvement statement

Patients or the public were not involved in the development of the research question or the design of this study nor in the conduct of the study.

Exposure

Physical heaviness of work was enquired at waves 1 to 3 with a single question: "How heavy is your work physically?". There were six response alternatives: 1) light sedentary work, 2) other sedentary work, 3) physically light work, involving standing and moving, 4) medium heavy work involving moving, 5) physically heavy work, and 6) physically very heavy work. The responses were categorized as: sedentary/physically light work, and medium to heavy physical work. We used responses from all three waves to form a five-class exposure variable categorized as: "no exposure", when reporting sedentary/physically light work in all three waves, "early exposure only", when reporting medium to heavy physical work only in wave 1, "later exposure only", when reporting medium to heavy physical work in waves 2 or 3 (89% responded to both waves 2 and 3), and "early and later exposure" when reporting medium to heavy physical work in wave 1 and in later adulthood in wave 2 and/or 3. All other possible response combinations formed a group "inconsistent exposure".

Outcomes

We examined primary health care visits due to a musculoskeletal diagnosis. The follow-up started from the day after returning wave 3 survey in 2011. Repeated visits were used for the main analyses. For an alternative analysis, time to the first visit was used as an outcome, and the follow-up from returning the survey in 2011 continued until the first primary health care visit, death (from Statistics Finland) or end of the follow-up (end of 2014), whichever occurred first. Data were obtained from the register of primary health care visits (Avohilmo) maintained by National Institute for Health and Welfare.[16] Diagnosis-specific data have been collected and were available from 2011 onwards. Visits due to *any musculoskeletal diagnosis* by International Classification of Diseases (ICD) version 10 codes M00-M99 were examined over the follow-up period. Additionally, two cause-specific outcome groups with the largest numbers of events were: 1) disorders of the spine and 2) upper extremity disorders. *Disorders of the spine* included any of the following diseases, surgeries or treatments (ICD-10 code): cervical disc disorders (M50), lumbar and other intervertebral disc disorders with radiculopathy (M51.1), other specified intervertebral disc displacement (M51.2), disc degeneration (M51.3), disc disorders (M51.8), intervertebral disc disorder, unspecified (M51.9), disc disorder/ disc disease (back disorders with radiation: M50, M51), other dorsopathies (M53), back pain / dorsalgia (back disorders without radiation: M54.1, M54.2, M54.3, M54.4, M54.5, M54.6, M54.8, M54.9), and lumbar disc herniation or sciatica (M51.1, M51.2, M54.3, and M54.4). *Upper extremity disorders* included any of the following diseases, surgeries or treatments: carpal tunnel syndrome, carpal tunnel release (G56.0, ACC51, ACC59), shoulder disorder (M75), medial epicondylitis, lateral epicondylitis, and periarthritis of wrist (M77.0, M77.1, M77.2, or M77.3). Additionally, the numbers of visits due to osteoarthritis (M15, M16, M17, M18) were examined, but found to be too low for statistical analyses (see Table 1).

Covariates

From the questionnaires we obtained information on possible confounders. We included sex and age at wave 1, and parental occupational status in childhood (1=upper non-manual, 2=lower non-manual, 3=upper manual, 4=lower manual). Smoking (ever smoker vs. non-smoker) and body mass index (BMI, kg/m^2 based on measured weight and height) were included as time varying covariates collected at baseline, 2001, 2007 and 2011. Measure for leisure-time physical activity (PA) was based on a set of questions requesting the frequency and intensity of PA, frequency of vigorous PA, hours spent on vigorous PA, average duration of a PA session, and participation in organized PA. Based on these questions a *physical activity index* was calculated (range 5-15, larger value indicating greater activity).[17] For PA, we used the maximum of the three measurements of the PA index in adulthood (2001, 2007 and 2011), as these data had plenty of missing values (N missing =730 in 2001, 150 in 2007 and 475 in 2011), but the patterns of PA have been observed to remain constant in adulthood.[18] Missing data on smoking were re-coded as "non-smoker". Number of missing observations varied by phase from 5 in 2007 to 369 in 1986, some of which were excluded due to missing data on other covariates. Missing data on BMI were imputed using mean of the study sample in the corresponding survey. Number of missing observations varied from 0 in 2001 to 411 in 1989, some of which were excluded due to missing data on other covariates. Although this is not the strongest imputation method we considered it was the most applicable one, as the method only concerned one covariate. All these covariates have been linked to back problems in prior studies[11 19-21] and smoking can be also considered as an indicator of low socioeconomic position, which may affect the choice of employment and further physical workload.

Statistical analyses

We used generalized estimating equation (GEE) models with Poisson distribution to assess associations between the five-class physical work exposure, "no exposure" serving as the reference group, and repeated primary health care visits due to MSD. This method was chosen as the GEE models permit specification of a working correlation matrix that accounts for the form of within-subject correlation of responses on dependent variables of many different distributions, including Poisson.[22] We ran models separately for all musculoskeletal visits, for disorders of the spine, and for upper extremity disorders. Two model specifications were used: Model 1 was adjusted for sex and age at baseline, Model 2 was additionally adjusted for parental occupational class, physical activity, and time-varying smoking and BMI. Results are presented as risk ratios (RR) with 95% confidence intervals (CI). As an alternative method, we ran the analyses using Cox proportional hazard models using time to the first visit as the outcome, which resulted in very similar findings (supplemental Table 1).

Results

Descriptive statistics of the analysis sample in total and by sex are shown in Table 1. At baseline, mean age was 20.5 (SD=2.9) years, and mean BMI 22.4 (SD=2.3), while the mean BMI during the follow-up was 25.5 (SD=4.8). Mean follow-up time for first visits due to any MSD was 3.2 (SD=0.87) years, due to spine disorders 3.4 (SD=0.63) years, and due to upper extremity disorders 3.4 (SD=0.50) years. In the total sample, prevalence of any musculoskeletal disease during the follow-up was 20%, that for spine disorders 10%, and that for upper extremity disorders 5%. Distributions of the outcomes and proportions of events in each of the five exposure groups in total and by sex are presented in Table 2. As shown in Table 2, the low numbers of events prevented sex-specific analyses.

Associations between physical heaviness of work and primary health care visits due to the three outcome groups are presented in Table 3. Overall, the age- and sex-adjusted estimates (Model 1) were slightly attenuated after including parental occupational status smoking, BMI and physical activity (Model 2). We observed an association between early exposure only and any musculoskeletal disorders (fully adjusted RR 1.55, 95% CI 1.05−2.28) and a slightly weaker association for later exposure only (RR 1.46, 95% 1.01−2.12). Early and later exposure had the strongest association with any visits due to MSD (RR 1.99, 95% CI 1.44−2.77).

For disorders of the spine, we observed an association for later exposure only (RR 2.40, 95% CI 1.41−4.06), inconsistent exposure (RR 2.30, 95% CI 1.34−3.95), and early and later exposure (RR 2.43, 95% CI 1.42−4.14). Effect estimates for visits due to upper extremity disorders were also positive, that for early and later exposure (HR 3.97, 95% CI 1.86−8.46) reaching statistical significance, although with a wide confidence interval.

Discussion

In this study, reporting both early and later exposure to heavy physical work was associated with objectively measured MSDs requiring primary health care visit in midlife. In addition, physical heaviness of work in early adulthood only was associated with an increased risk of primary health care visit due to any MSD, and exposure in later adulthood only was associated with any MSD and disorders of the spine. These diagnosis-specific findings are in line with our prior findings for self-reported low back pain.[8] Although our current analyses may have lacked power to detect precise associations, particularly for upper extremity disorders, the findings suggest that physical work exposure is also a predictor of objectively measured MSDs even after considering behavioural factors and parental socioeconomic position.

Longitudinal studies on the associations between physical work exposures and objectively measured MSDs are scarce. Specifically, we are not aware of studies that would have collected and used data on work-related physical exposures of participants from early to later adulthood, and health care visits due to MSDs in midlife. Some evidence exists regarding physical work exposures and musculoskeletal pain or disorders at an early stage of the working career. In one cross-sectional study repetitive and asymmetric demands, including high probability of repetitive tasks, bending or rotation movements and manual materials handling, was associated with the presence of neck/shoulder pain and severity of upper- and lower-back pain among 21-year-old employees.[23] Another cross-sectional study among less than 30-year-old employees reported similar results regarding the association between physical work exposures (e.g. repetitive flexion or rotation movements of the trunk, and more than three years in a job including lifting more than 25 kg at least once an hour) and low back pain.[24] However, in these studies follow-up for mid-life musculoskeletal disorders was not available. Timing of outcome measurement seems essential as it is likely that there are differences in associations between physical work and MSD among 20-35, 36-49 and over 50-year old employees.[25]

Several studies have reported associations between physical work exposures and increased risk of objectively measured disability retirement due to MSD.[5 26-28] However, only one of these studies examined how exposure in early adulthood was associated with disability retirement due to MSD in mid-life.[28] Moreover, only a few studies have reported associations between cumulative exposure to physical work throughout the work career and objectively measured sickness absence or disability retirement in general,[29] or due to disability retirement due to MSD in particular.[6] These findings have been in line with ours, although the cumulative exposure in the study focusing on MSD was assessed using a job exposure matrix.

Some limitations of this study need to be acknowledged. We used self-reported assessment of physical heaviness of work that was based on a single question. Consequently, the specificity of the exposure, e.g. regarding exposure of different parts of the body, is low. Although such questions have widely been used in epidemiological studies and have indicated good validity,[30] this may partly explain the non-significant associations between physical work and upper extremity disorders. We also used a dichotomized physical heaviness of work measure where medium and heavy/very heavy work were combined as the proportion of those with heavy/very heavy work was rather low (10% at early adulthood). The used cut-off may have attenuated the observed associations if medium heavy work had substantially weaker association with health care visits than heavy/very heavy work. We cannot rule out the possibility of changes in the exposure or outcomes between the survey waves, which may have caused under- or over-estimation of the associations. However, the long follow-up enabled us to examine the long-term consequences of early and later physical work and midlife musculoskeletal health problems that were objectively measured. Some healthy worker effect may have attenuated the findings as we required minimum of two responses (from early and later adulthood) regarding physical heaviness of work and those with physically strenuous work or with musculoskeletal problems may have left employment before the second survey. It can also be speculated that primary health care visits with musculoskeletal diagnosis in midlife are mostly a result of pain complaints. Severe pain may interfere with work activities and induce need for sickness absence, which may be the primary motivation for the visit to a physician. Thus, the used outcomes may reflect the severity of work disability due to a subjective measure of musculoskeletal pain. The follow-up period for the outcomes was not very long and unobserved changes in the exposure or covariates during the outcome follow-up could have caused some bias to the findings resulting in under- or overestimation of the observed associations. However, the major strength of this work is the prospective study design with three repeated assessments of physical heaviness of work that were initiated in early adulthood. Moreover, the used cohort data were representative of the general population with relatively little loss to follow-up.[15] As we used register data, only persons who emigrate will no more have registered health care visits. This suggests good generalizability to the Finnish working population, while more caution is needed when assessing generalizability to other countries with different health care systems.

In summary, our findings suggest that exposure to heavy physical work over the work career contributes to the high burden in the health care. Therefore, preventive actions against musculoskeletal problems due to physically heavy work in early adulthood, later adulthood and cumulatively throughout the work career are needed. One possible action, specifically among young employees, might be good introduction to ergonomic ways to work. Guidance on how to recover from physical work tasks is also important; for example, at individual level recovery training has been seen beneficial to the employees.[31] At organizational level, procedures enabling recovery during the work day could include task variation and convenient work-break schedules,[31] which are likely to be applicable throughout the work career.

A competing interest declaration

All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare that (1) JIH and TLa have support from the Academy of Finland; (2) JIH and TLa have no relationships with the Finnish Academy that might have an interest in the submitted work in the previous 3 years; (3) their spouses, partners, or children have no financial relationships that may be relevant to the submitted work; and (4) JIH, RS, HS, MM, SS, EV-J, MK, TLe, OR and TLa have no non-financial interests that may be relevant to the submitted work.

Authors' contributions JIH, RS, MM, HS, EV-J, SS and TLa conceived and designed the experiments, TLa analysed the data, JIH wrote the first draft of the article, MK, TLe and OR contributed materials and/or analysis tools. TLa, MK, TLe and OR contributed to the funding of the study. TLa is the guarantor of the study. All authors were involved in interpretation of the findings, writing the paper and approved the submitted and published versions.

Funding The research was funded by the Finnish Academy (grant numbers 287488 and 319200 for TLa and JIH). The Young Finns Study has been financially supported by the Academy of Finland: grants 286284, 134309 (Eye), 126925, 121584, 124282, 129364, 129378 (Salve), 117787 (Gendi), and 41071 (Skidi); the Social Insurance Institution of Finland; Competitive State Research Financing of the Expert Responsibility area of Kuopio, Tampere and Turku University Hospitals (grant X51001); Juho Vainio Foundation; Paavo Nurmi Foundation; Finnish Foundation for Cardiovascular Research; Finnish Cultural Foundation; The Sigrid Juselius Foundation; Tampere Tuberculosis Foundation; Emil Aaltonen Foundation; Yrjö Jahnsson Foundation; Signe and Ane Gyllenberg Foundation; Diabetes Research Foundation of Finnish Diabetes Association; and EU Horizon 2020 (grant 755320 for TAXINOMISIS); and European Research Council (grant 742927 for MULTIEPIGEN project); Tampere University Hospital Supporting Foundation.

Ethics approval The study has received ethical approval from the Ethics Committee of the Hospital District of Southwest Finland on September 21st, 2010.

Data sharing TLa had access to an anonymized subset of the data that were used for the analyses. OTR had full access to all raw data. Raw data from the study are not available due to confidentiality and sensitivity issues. Subset of raw data can be requested from OTR olli.raitakari[at]utu.fi.

Acknowledgements The authors thank statistician Niina Kartiosuo for her help with the formation of the analysis dataset.

Figure Legend

Figure 1. Flow chart of the sample selection.

References

1 OECD. Sickness, Disability and Work: Breaking the Barriers. A Synthesis of Findings across OECD Countries OECD Publishing, Paris. 2010.

2 Linaker C, Harris EC, Cooper C, Coggon D, Palmer KT. The burden of sickness absence from musculoskeletal causes in Great Britain. *Occup Med (Lond)* 2011;61:458-64.

3 Statistics Finland. Recipients of disability pension 2018.

4 Bevan S. Economic impact of musculoskeletal disorders (MSDs) on work in Europe. *Best Pract Res Clin Rheumatol* 2015;29:356-73.

5 Foss L, Gravseth HM, Kristensen P et al. The impact of workplace risk factors on long-term musculoskeletal sickness absence: a registry-based 5-year follow-up from the Oslo health study. *J Occup Environ Med* 2011;53:1478-82.

6 Ervasti J, Pietilainen O, Rahkonen O et al. Long-term exposure to heavy physical work, disability pension due to musculoskeletal disorders and all-cause mortality: 20-year follow-up-introducing Helsinki Health Study job exposure matrix. *Int Arch Occup Environ Health* 2018.

7 Madsen IEH, Gupta N, Budtz-Jorgensen E et al. Physical work demands and psychosocial working conditions as predictors of musculoskeletal pain: a cohort study comparing self-reported and job exposure matrix measurements. *Occup Environ Med* 2018;75:752-758.

8 Lallukka T, Viikari-Juntura E, Viikari J et al. Early work-related physical exposures and low back pain in midlife: the Cardiovascular Risk in Young Finns Study. *Occup Environ Med* 2017;74:163-168.

9 Kjellberg K, Lundin A, Falkstedt D, Allebeck P, Hemmingsson T. Long-term physical workload in middle age and disability pension in men and women: a follow-up study of Swedish cohorts. *Int Arch Occup Environ Health* 2016;89:1239-1250.

10 Sundstrup E, Hansen AM, Mortensen EL et al. Retrospectively assessed physical work environment during working life and risk of sickness absence and labour market exit among older workers. *Occup Environ Med* 2018;75:114-123.

11 Lallukka T, Viikari-Juntura E, Raitakari OT et al. Childhood and adult socio-economic position and social mobility as determinants of low back pain outcomes. *Eur J Pain* 2014;18:128-38.

12 Power C, Atherton K, Strachan DP et al. Life-course influences on health in British adults: effects of socio-economic position in childhood and adulthood. *Int J Epidemiol* 2007;36:532-9.

13 Laukkonen M-L. Pienituloisten perheiden ylioppilaat välttävät riskiä pääsykokeita painottavissa opiskelijavalinnoissa [High school graduates from low income families evade risk related to student admission emphasizing entrance examinations]: ETLA 2018.

14 Whiston SC, Keller BK. The Influences of the Family of Origin on Career Development: A Review and Analysis. *The Counceling Psychologist* 2004;32:493-568.

15 Raitakari OT, Juonala M, Rönnemaa T et al. Cohort profile: the cardiovascular risk in Young Finns Study. *Int J Epidemiol* 2008;37:1220-6.

16 National Institute for Health and Welfare. Register of Primary Health Care visits, Helsinki: National Institute for Health and Welfare 2019.

17 Rovio SP, Yang X, Kankaanpaa A et al. Longitudinal physical activity trajectories from childhood to adulthood and their determinants: The Young Finns Study. *Scand J Med Sci Sports* 2018;28:1073-1083.

18 Telama R, Yang X, Leskinen E et al. Tracking of physical activity from early childhood through youth into adulthood. *Med Sci Sports Exerc* 2014;46:955-62.

19 Shiri R, Karppinen J, Leino-Arjas P, Solovieva S, Viikari-Juntura E. The association between smoking and low back pain: a meta-analysis. *Am J Med* 2010;123:87.e7-35.

20 -. The association between obesity and low back pain: a meta-analysis. *Am J Epidemiol* 2010;171:135-54.

21 Shiri R, Euro U, Heliovaara M et al. Lifestyle Risk Factors Increase the Risk of Hospitalization for Sciatica: Findings of Four Prospective Cohort Studies. *Am J Med* 2017;130:1408-1414.e6.

22 Ballinger GA. Using Generalized Estimating Equations for Longitudinal Data Analysis. *Organizational Research Methods* 2004;7:127-150.

23 Lourenco S, Araujo F, Severo M, Cunha Miranda L, Carnide F, Lucas R. Patterns of biomechanical demands are associated with musculoskeletal pain in the beginning of professional life: a population-based study. *Scand J Work Environ Health* 2015;41:234-46.

24 Van Nieuwenhuyse A, Fatkhutdinova L, Verbeke G et al. Risk factors for first-ever low back pain among workers in their first employment. *Occup Med (Lond)* 2004;54:513-9.

25 Oakman J, Neupane S, Nygard CH. Does age matter in predicting musculoskeletal disorder risk? An analysis of workplace predictors over 4 years. *Int Arch Occup Environ Health* 2016;89:1127-36.

26 Lahelma E, Laaksonen M, Lallukka T et al. Working conditions as risk factors for disability retirement: a longitudinal register linkage study. *BMC Public Health* 2012;12:309.

27 Robroek SJW, Jarvholm B, van der Beek AJ, Proper KI, Wahlstrom J, Burdorf A. Influence of obesity and physical workload on disability benefits among construction workers followed up for 37 years. *Occup Environ Med* 2017;74:621-627.

28 Ropponen A, Svedberg P, Koskenvuo M, Silventoinen K, Kaprio J. Physical work load and psychological stress of daily activities as predictors of disability pension due to musculoskeletal disorders. *Scand J Public Health* 2014;42:370-6.

29 Sundstrup E, Hansen AM, Mortensen EL et al. Cumulative occupational mechanical exposures during working life and risk of sickness absence and disability pension: prospective cohort study. *Scand J Work Environ Health* 2017;43:415-425.

30 Stock SR, Fernandes R, Delisle A, Vezina N. Reproducibility and validity of workers' self-reports of physical work demands. *Scand J Work Environ Health* 2005;31:409-37.

31 Verbeek J, Ruotsalainen J, Laitinen J et al. Interventions to enhance recovery in healthy workers; a scoping review. *Occup Med (Lond)* 2018.

Table 1. Descriptive statistics of the study population at baseline.

	All	
Variable	N	%
Total individuals	1065	100
Women	446	42
Men	610	58
Parental occupational status		
upper non-manual	152	14
lower non-manual	447	42
upper manual	282	27
lower manual	175	17
Ever smokers	516	49
Low physical activity index*	710	67
Cumulative exposure to heavy physical work		
No exposure	523	49
Early exposure only	124	13
Later exposure only	130	12
Inconsistent exposure	118	11
Early and later exposure	161	15
Outcomes (-)		
Any musculoskeletal disease	221	21
Disorders of the spine	107	10
Upper extremity disorders	52	5
Osteoarthritis	16	1.5

* Index score 5-10

Table 2. Number of observations and proportions (%) of primary health care visits due to musculoskeletal diseases by the exposure categories for physical heaviness of work between 2011 and 2014.

Physical heaviness of work	Any musculoskeletal disease N_{obs} (%)	Disorders of the spine N_{obs} (%)	Upper extremity disorders N_{obs} (%)	Osteroarthritis N_{obs} (%)
All	1083	527	253	79
No exposure	405 (37)	168 (32)	66 (26)	44 (56)
Early exposure	137 (13)	64 (12)	34 (13)	20 (25)
Later exposure	156 (14)	102 (19)	40 (16)	5 (6)
Inconsistent exposure	168 (16)	85 (16)	34 (13)	10 (13)
Early and later exposure	217 (20)	108 (21)	79 (31)	0 (0)
Women	730	353	165	59
No exposure	334 (46)	148 (42)	47 (28)	35 (58)
Early exposure	58 (8)	29 (8)	14 (8)	15 (25)
Later exposure	107 (15)	63 (18)	30 (18)	5 (8)
Inconsistent exposure	128 (18)	55 (16)	34 (21)	5 (8)
Early and later exposure	103 (14)	58 (16)	40 (24)	0 (0)
Men	353	174	88	20
No exposure	71 (20)	20 (11)	19 (22)	10 (50)
Early exposure	79 (22)	35 (20)	20 (23)	5 (25)
Later exposure	49 (14)	39 (23)	10 (11)	0 (0)
Inconsistent exposure	40 (11)	30 (17)	0 (0)	5 (25)
Early and later exposure	115 (32)	50 (29)	39 (44)	0 (0)

Table 3. Risk ratios for primary health care visits due to musculoskeletal diseases in relation to early and later exposure to heavy physical work.

	Model 1*			Model 2†		
Physical heaviness of work	RR	95% CI		RR	95% CI	
Any musculoskeletal disease						
No exposure	1			1		
Early exposure	1.65	1.12	2.41	1.55	1.05	2.28
Later exposure	1.57	1.09	2.24	1.46	1.01	2.12
Inconsistent exposure	1.90	1.35	2.67	1.87	1.34	2.61
Early and later exposure	2.14	1.55	2.97	1.99	1.44	2.77
Disorders of the spine						
No exposure	1			1		
Early exposure	1.87	1.02	3.42	1.76	0.96	3.22
Later exposure	2.51	1.51	4.18	2.40	1.41	4.06
Inconsistent exposure	2.32	1.35	3.99	2.30	1.34	3.95
Early and later exposure	2.62	1.56	4.40	2.43	1.42	4.14
Upper extremity disorders						
No exposure	1			1		
Early exposure	2.50	1.03	6.11	2.16	0.87	5.37
Later exposure	2.33	1.00	5.67	2.02	0.85	4.85
Inconsistent exposure	2.33	0.96	5.67	2.26	0.94	5.43
Early and later exposure	4.79	2.28	10.1	3.97	1.86	8.46

* Model 1 adjusted for age and sex

† Model 2 adjusted for age, sex, smoking, BMI, physical activity and parental occupational class

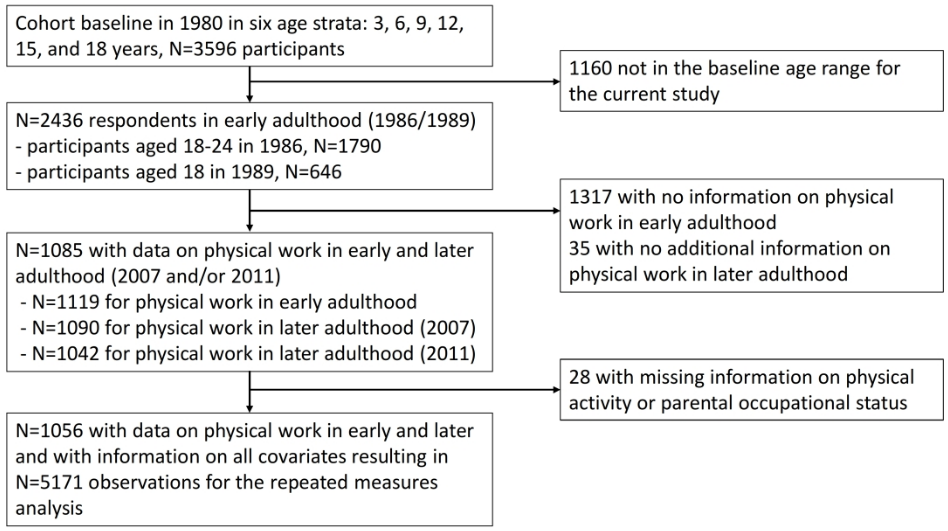


Figure 1. Flow chart of the sample selection.

Supplemental material

Exposure to heavy physical work from early to later adulthood and primary health care visits due to musculoskeletal diseases in midlife: a register linked study

Jaana I. Halonen, Rahman Shiri, Minna Mänty, Hilla Sumanen, Svetlana Solovieva, Eira Viikari-Juntura, Mika Kähönen, Terho Lehtimäki, Olli T. Raitakari, Tea Lallukka

Supplemental Table 1. Associations between early and later exposure to heavy physical work and primary health care visits due to musculoskeletal diseases from Cox proportional hazard models.

	Model 1*			Model 2†		
Physical heaviness of work	HR	95% CI		HR	95% CI	
Any musculoskeletal disease						
No exposure	1			1		
Early exposure	1.95	1.22	3.11	1.90	1.18	3.06
Later exposure	1.36	0.84	2.22	1.32	0.81	2.16
Inconsistent exposure	2.01	1.27	3.17	2.01	1.27	3.17
Early and later exposure	2.41	1.56	3.73	2.26	1.45	3.52
Disorders of the spine						
No exposure	1			1		
Early exposure	2.43	1.17	5.05	2.37	1.14	4.95
Later exposure	2.54	1.30	4.96	2.48	1.26	4.88
Inconsistent exposure	2.36	1.15	4.85	2.38	1.15	4.89
Early and later exposure	3.51	1.81	6.83	3.29	1.67	6.48
Upper extremity disorders						
No exposure	1			1		
Early exposure	3.75	1.28	11.0	3.38	1.14	10.1
Later exposure	2.48	0.80	7.64	2.22	0.72	6.87
Inconsistent exposure	2.46	0.74	8.17	2.27	0.68	7.62
Early and later exposure	6.12	2.33	16.0	4.84	1.81	12.9

* Model 1 adjusted for age and sex
† Model 2 adjusted for age, sex, smoking, BMI, and parental occupational class

STROBE Statement— Halonen JI et al. Exposure to heavy physical work from early to later adulthood and primary health care visits due to musculoskeletal diseases in midlife: a register linked study

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **SEE Abstract on p. 2**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **SEE Abstract on p. 2**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **SEE p. 4**
Objectives	3	State specific objectives, including any pre-specified hypotheses **SEE p. 5**
Methods		
Study design	4	Present key elements of study design early in the paper **SEE p. 5 for description of the study cohort**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **SEE pp. 5-6 (setting), 6 (exposure), 6-7 (outcomes and follow-up)**
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up **SEE p. 5**
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed **NA**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **SEE pp. 6 (exposure), 6-7 (outcome), 8 (covariates)**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **SEE pp. 5 (setting), 6 (exposure), 6-7 (outcomes), 8 (covariates)**
Bias	9	Describe any efforts to address potential sources of bias **SEE pp. 8-9 (covariate adjustments and alternative analysis method)**
Study size	10	Explain how the study size was arrived at **SEE p. 5 and Figure 1 (flow chart)**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **SEE pp. 6 (exposure), 6-7 (outcomes), 8 (covariates)**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding **SEE pp. 8-9**
		(*b*) Describe any methods used to examine subgroups and interactions **SEE pp. 8-9**
		(*c*) Explain how missing data were addressed **SEE p. 8 (covariates)**
		(*d*) If applicable, explain how loss to follow-up was addressed **NA**
		(*e*) Describe any sensitivity analyses **SEE p. 9**

Results

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **SEE p. 5 and Figure 1**
		(b) Give reasons for non-participation at each stage **NA**
		(c) Consider use of a flow diagram **Figure 1 is a flow diagram**
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **SEE p. 9 and Table 1**
		(b) Indicate number of participants with missing data for each variable of interest **Those with missing data were excluded, see page 5 and Figure 1.**
		(c) Summarise follow-up time (eg, average and total amount) **NA**
Outcome data	15*	Report numbers of outcome events or summary measures over time **SEE Table 2.**
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included **SEE Table 3**
		(*b*) Report category boundaries when continuous variables were categorized **See pp. 6 (exposure), 8 (covariates)**
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period **Unadjusted absolute risks provided in the abstract on page 2 and on page 9.**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses **SEE p. 9 and supplemental Table 1.**
Discussion		
Key results	18	Summarise key results with reference to study objectives **SEE p. 10**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **SEE pp. 11-12**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **SEE p. 13**
Generalizability	21	Discuss the generalizability (external validity) of the study results **SEE p. 12**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **SEE p. 14**

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.